Road pricing: a transport geographical perspective

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Road pricing: a transport geographical perspective

Geographical accessibility and short and long-term behavioural effects

Wegbeprijzing: een transportgeografisch perspectief
Geografische bereikbaarheid en korte en lange termijn gedragseffecten

(met een samenvatting in het Nederlands)

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Taede Tillema

geboren op 27 februari 1979 te Delfzijl

Promotor:
Prof. Dr. G.P. van Wee

Co-promotoren:
Dr. T. de Jong
Dr.ir. D.F. Ettema

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Voorwoord

In april 2002 ben ik als assistent in opleiding begonnen met een onderzoek naar het bestuderen van de effecten van wegbeprijzing vanuit een transportgeografisch perspectief. Ik heb dit onderzoek uitgevoerd binnen het kader van een door Connekt/NWO gefinancierd multidisciplinair project waarin in totaal vier Nederlandse universiteiten participeerden. Na een paar drukke laatste maanden waarin ik zowel aan dit proefschrift als aan mijn nieuwe baan werkte, is het eindelijk af. Ik ben daar erg blij mee! Graag wil ik in dit voorwoord alle mensen bedanken die cruciaal zijn geweest voor een succesvolle afronding van dit proefschrift.

Allereerst gaat mijn dank uit naar mijn promotor Bert van Wee en copromotor Tom de Jong. Zij hebben het aangedurfd om mij op dit project aan te nemen ondanks mijn iets andere, technische, achtergrond. Bert, alhoewel je in mijn eerste jaar als AIO naar Delft vertrok, heb ik totaal niet het gevoel gehad te weinig begeleiding te hebben gekregen. Naast zo nu en dan een afspraak in de stationsrestauratie in Utrecht was er veelvuldig contact via de mail. Ik heb het als erg prettig ervaren dat je altijd zo snel reageerde. Daarnaast ben ik ook onder de indruk van je inhoudelijke kennis en van het feit dat je voortdurend op de hoogte was van zaken die speelden in mijn project. Tom, ook jouw begeleiding is zeer belangrijk geweest. Je kennis op het gebied van bereikbaarheid, Flowmap en andere GIS-applicaties was onmisbaar voor het goed kunnen afronden van het proefschrift. Daarnaast heb ik de werksfeer gedurende het hele project als uitermate prettig ervaren. Je was altijd geïnteresseerd in hoe het ging. Verder kon ik altijd bij je binnenlopen om wat te vragen. Maar ook aan de activiteiten buiten werktijd, zoals de AIO fiets- en wandeltochten en de etentjes bewaar ik goede herinneringen. In een later stadium is copromotor Dick Ettema bij het project betrokken geraakt. Dick, bedankt voor de tijd en inspanning die je in mijn project hebt gestoken. Ik heb kunnen profiteren van je kennis op het gebied van stated preference experimenten en discrete keuze modellen. Verder waren je kritische opmerkingen belangrijk om de verschillende hoofdstukken te verbeteren.

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Taede

Utrecht, december 2006

1 - Introduction

1.1 - Introduction

Road transport is an essential service in any society. Goods have to be transported between manufacturers and consumers and passenger transport, both private and public, allows people to join activities at different locations and during different time intervals. The benefits of transport are many and varied: an efficient transport system is a major contributor to economic growth, competitiveness and employment. Therefore, an efficient transport system is important.

An efficient transport system is highly dependent on the infrastructure and on the service level of the infrastructure. Socio-economic and demographic changes and (global) economic developments, however, have increased mobility (demand) and have put pressure on the service level of the infrastructure. Traffic intensities are increasing every year and the road supply can often not handle the increasing demand for travel; congestion occurs in and around bottlenecks and especially during peak hours. For an extensive overview of congestion (data, factors influencing congestion, etc.) see Bovy (2001) and Bovy and Salomon (1999). This trend can be seen in urbanised areas all over the world. Time losses, as a consequence of congestion, have a negative economic impact. The value of the 'lost vehicle hours' on the Dutch main road network, for instance, is approximately € 0.8 billion when only congestion delays are priced and almost double that value when hidden costs (i.e. due to changes in people's travel behaviour) are taken into account (Koopmans and Kroes, 2004). However, the actual costs may be even higher because freight, international and inter-zone urban traffic were excluded (see Koopmans and Kroes, 2004). Moreover, congestion has an impact (both positive and negative) on road safety, emissions and noise (ECMT, 1999).

In the recent past, public institutions have primarily dealt with increasing demands for traffic by building new infrastructure in order to enlarge supply. Road traffic forecasts showing where capacity problems could be expected have led to road building schemes[1]. However, experience has taught us that this boost in supply has led to an increase in traffic demand (Goodwin, 1996). This is a cyclic process. Nowadays, policies and measures which influence traffic demand are becoming more popular, for instance measures that relate car costs more directly to driving. This means that the variable costs (e.g. kilometre costs) are given a greater share in total travel costs. Relating travel costs more directly to car use (transferring fixed to variable costs) can create an incentive for categories of travellers and firms to change their behaviour. Demand-oriented policies, however, may do more than form a substitute for building new infrastructure. Measures influencing traffic demand and the supplied road capacity can also be implemented at the same time (e.g. see Ministry of Transport, Public Works and Water Management, 2006), possibly reinforcing each other in reducing congestion (effects).

1 See also the policy process called "predict-and-provide paradigm" (Banister, 2002a).

Additionally, one opinion in contemporary policy is that road users have to take full account of the external costs they cause. External costs arise whenever the well-being of individuals is affected by the (economic) activities of others who ignore this 'spill over' when taking their decisions (European Commission, 2001). Traffic congestion (effects) can be regarded as a form of external costs. When people drive their cars they generally do not consider the extra costs they may impose on other car drivers, for example in the form of extra delays. Such external costs related to costs inside the transport system, such as congestion and accident costs, can be categorized as in-system costs. Nevertheless, all costs outside the transport system are also part of the externalities. Examples are environmental costs, such as noise pollution, local air pollution, acidification and climate change (Van Wee, 1995). A choice may be made to internalise external costs (i.e. the polluter pays). From an economic point of view this means that the marginal willingness to pay must be equal to the total marginal social costs. The internalisation of the externalities can be reached by levying a toll, which represents both the external congestion and environmental costs (see for example: Blauwens, 1998; De Wit and Van Gent, 1998; Van Wee, 1995; Verhoef, 2000; Ferrari, 2002).

(Road) pricing policies are more and more considered or even implemented in urbanised areas around the world, the aim being to alleviate (some of the) above-mentioned external traffic-related costs. Especially the aim of reducing congestion (costs/effects) seems to be an important reason for implementation (see e.g. Ministry of Transport, Public Works and Water Management, 2006; European Commission[2], 2001; Tfl, 2003; Phang and Toh, 1997). However, another motivation that has not yet been mentioned may be the generation of revenues that can be used to build and maintain infrastructure. Road pricing is also an important political topic of debate in the Netherlands (Nationaal platform anders betalen voor mobiliteit, 2005) and the Ministry of Transport, Public Works and Water Management intends to implement nation-wide a differentiated (i.e. to time, place and environmental costs) kilometre charge as soon as the implementation costs are 'low enough' (Ministry of Transport, Public Works and Water Management, 2006). However, no formal decision (i.e. by parliament) to implement a type of price measure has yet been made. And it is expected that public acceptability will play an important role in the final decision whether or not to go ahead with its implementation. In the Netherlands, public acceptability seems low (Rienstra *et al.*, 1999). Partly, this is due to the fact that not much is known about the effects a charge may have. People may feel as if they are paying for something that might not even work. It is clear, therefore, that it is necessary to obtain greater insight into the consequences of various transport charges in terms of behaviour and acceptability. This thesis specifically looks at transport pricing[3] effects from a geographical perspective. On the one hand the thesis is concerned with modelling geographical accessibility (effects) due to transport pricing and on the other hand it provides insight into the behavioural (especially relocation) effects of the introduction of pricing measures.

2 The importance of internalising externals costs can also be found in the document "European transport policy for 2010: time to decide".

3 Within this thesis only transport pricing measures are regarded that actually involve some sort of 'pricing of the roads' (for example kilometre charges, cordon charges, etc.). In most cases these measures aim specifically at reducing congestion and therefore can often be defined as road or congestion pricing measures. Fuel prices or fixed car taxes are not taken into account as transport pricing measures within this thesis.

This PhD-thesis was written in the context of a larger multidisciplinary project called 'a Multi-Disciplinary study of Pricing policies In Transport' (MD-PIT). In this project pricing measure effects are studied from an economic, traffic engineering, psychological and geographical perspective. Four universities are involved: the Free University of Amsterdam (economic perspective), Delft University of Technology (traffic engineering perspective), Groningen University (psychological perspective) and Utrecht University (geographical perspective). An overview of the contents of the MD-PIT project and of the way the tasks involved have been divided among the various research institutes is presented in Appendix A. The MD-PIT project has been funded by Connekt/NWO and is part of the VEV[4] programme. The aim of the overall MD-PIT project can be defined as:

Providing a theoretical and empirical evaluation of the direct and indirect effects of practically possible transport pricing policies from a multidisciplinary perspective. The effects studied include behavioural responses and their consequences, also from a spatial and a network perspective, as well as acceptability issues of various pricing and tax recycling schemes. The evaluation includes the derivation and formulation of policy implications. Specific features of the project include the focus on dynamic aspects (both in the short run and in the long run), the recognition of heterogeneity (i.e. the consideration of different groups), and the explicit choice for a network and spatial perspective. [MD-PIT proposal, 2002]

Within the overall MD-PIT project five theses in all are to be delivered. The current thesis on 'the geographical perspective' forms one of them. Focusing now on the 'geographical perspective', the outline of the remaining part of this introductory (first) chapter is as follows. Section 1.2 links pricing to the geographical perspective, consisting of geographical accessibility and (re)location choices. Section 1.3 gives a problem definition and formulates the research goals underlying this thesis. The research goals are worked out into research questions in section 1.4. Section 1.5 finally, describes the general outline of this thesis.

1.2 - Transport pricing policies: a geographical perspective

In analysing the consequences of pricing measures, different criteria can be used. Verhoef *et al.* (2004) mentioned the following three: effectiveness, efficiency and acceptability. Effectiveness can be formulated as the extent to which a policy (measure) reaches a certain goal; studying the behavioural effects of road pricing policies can shed light on this effectiveness. Efficiency can be seen as the extent to which the policy (measure) increases the social welfare (in broad definition) (see Verhoef *et al.*, 2004). And finally, the acceptance is the extent to which the policy (measure) is supported by society. This thesis looks specifically at the effectiveness of pricing measures from a transport geographical perspective: geographical accessibility and (longer-term) behavioural effects.

4 Connekt is an innovation network of traffic and transport in the Netherlands (see www.connekt.nl); NWO is the Dutch Organisation for Scientific Research (see www.nwo.nl); VEV is the traffic and transport stimulus plan that consists of four projects, of which MD-PIT is one.

The introduction of a road pricing measure leads to changes in the transport costs on (certain) roads in a network at a certain time, possibly influencing the geographical accessibility of (groups of) people or firms at certain locations. Geographical accessibility is an important concept in transport geography. It combines characteristics of the transport system (e.g. travel resistance) and the land use system (e.g. location of activities such as job locations). Geographical accessibility is a theoretical notion which is often used as an 'intermediate' concept in land-use transport modelling (see Wegner and Fürst, 1999): changes in the transport resistance affect the geographical accessibility (i.e. intermediate concept) of agents and possible accessibility changes may result in categories of people and firms deciding to change their short (e.g. trip behaviour changes) and/or long-term (e.g. location) behaviour. These behavioural changes in turn have an impact on the land use and transport system and thus change accessibility (see also chapter 2, section 2.3 for more insight into this land use transport interaction). Geographical accessibility, however, is not only used as a phase in land-use-transport interaction modelling. Accessibility can also be applied as a research indicator itself (see, for example, Geurs, 2006; Geurs and Ritsema van Eck, 2001). Accessibility indicators or measures give the opportunity to gain a quick and interpretable insight into the (accessibility) effects as a result of changes in the land-use or transport system (e.g. caused by certain policy interventions). These characteristics also make accessibility indicators a useful policy tool to assess (transport geographical) effects due to transport pricing, possibly in addition to economic welfare analyses. Whereas economic analyses are suitable for determining average welfare effects of road pricing measures, such analyses do not provide insight into the influence of road pricing on the (actual) geographical accessibility of different groups of people living and conducting activities at different locations. From a policy perspective it may be worthwhile to take a closer look at such differentiated accessibility effects before actually implementing a pricing measure. Then, if effects are not as expected or intended, the measure can still be modified before the actual start of the (costly) implementation process.

In contrast to the role of accessibility as a theoretical modelling concept for assessing impacts of traffic policies (for example road pricing), short and long-term behavioural changes of households and firms form the 'visible' effects of pricing. In the *short-term,* households and firms may, depending on the type of pricing, decide to change their daily travel pattern[5] (e.g. mode choice, departure time, etc.). Besides, firms may change their employee (compensation) policy and/or for example their product/service prices. Furthermore, (re)location choices form the *geographical (longer-term) effects*. A distinction can be made between *relocation* and *location choices* (Rossi, 1955; Moore, 1972; Weinburg, 1979; Vickerman, 1984). Road pricing costs may have an impact on the (perceived) travel impedance and form a trigger for households and/or firms to *relocate* (i.e. to decide to look for a new location). In the medium to long-term, households may, for example, decide to make changes in their daily or non-daily shopping locations, their recreational/leisure locations, etc. In the even longer-term, households can change locations where they work or live. Moreover, the relocation behaviour of firms may also be influenced by the introduction of road pricing. In the medium to longer-term, firms may decide to choose supplier(s) and/or customer(s) elsewhere. In the longer-term, firms can decide to move their business location altogether.

5 Possible short-term changes due to road pricing are (dependent on the type of measure) in random order: changes in route choice, departure time, the choice of the mode of transport and in the frequency of traveling (May and Milne, 2000).

In addition to being a trigger for relocation, the costs of pricing measures may influence the actual *choice of an activity location* (e.g. where to settle, work, etc.). On the one hand transport pricing costs may have a direct impact on the actual location choice(s) when the choice to relocate has been made specifically due to a pricing measure. On the other hand, pricing-related costs may also influence the final choice of location even if a decision to relocate has been taken for other reasons. Finally, a (road) pricing measure may influence the 'initial' location choices of households and firms. This can be the case, for example, when households choose to enter the housing market or when firms start up or come from abroad.

Obtaining insight into the extent to which location choices of (certain) households and firms are influenced by road pricing measures is not only important from the point of view of studying the whole range of (short-term as well as long-term) behavioural effects of road pricing. (Re)location choices may also have consequences for travel circumstances, in the sense that changes in peoples travel pattern may occur. This ultimately affects traffic densities and congestion levels in particular parts of the transportation network. Therefore, in order to evaluate the transportation effects of transport pricing in the longer-term it is important to look at relocation effects as well. Additionally, due to activity relocations, the equilibrium between demand and supply of locations and houses (in certain areas) may be distorted (at an aggregate level). These changes in demand and supply can, next to other influencing factors, have an effect on housing and land prices, which in turn influence the choices to relocate as well as the final decision where to settle/locate. In the end these relocation changes may alter the land-use pattern in (certain) regions, thereby affecting the entire spatial configuration of activity locations. Nevertheless, a good assessment of long-term (location) decisions cannot be made without also having insight into short-term (travel) changes. Short-term changes are (often) more likely to be made than long-term changes. If these short-term changes due to pricing do not lead to satisfactory outcomes or when people or firms are prevented from making certain preferred short-term changes, they can decide in favour of longer-term changes.

In summary, geographical accessibility indicators may be used to estimate ex ante (i.e. before actual implementation) to what extent different groups of people (with varying characteristics) living at different locations 'gain or lose' from policy measures such as road pricing. When a road pricing measure is implemented people may, for example due to a change in their perceived accessibility, decide to change their short-term travel behaviour or longer-term location (geographical) behaviour depending on what they feel is in their best interest.

1.3 - Problem definition and research goals

As described in section 1.2, accessibility indicators are useful tools to gain quick insight into the effectiveness of (traffic) policy measures such as road pricing for different groups of people living and participating in activities at different locations. Different categories of geographical accessibility indicators/measures exist (see section 2.4.2 for an overview). These accessibility indicators range from measures that focus on computing accessibility at an aggregate level to measures that operate at a disaggregate scale. Next to that, existing measures vary with respect to whether they measure actual accessibility, such as the number of opportunities (for example jobs) available within a certain travel time limit, or the 'valuation' of accessibility, such as the value/utility an individual or group of individuals place on accessibility (see also section 2.4.2 for this difference). These accessibility measures may not all be equally useful for modelling the accessibility effects due to pricing measures. Their suitability depends largely on criteria that are regarded as important in modelling accessibility effects. Examples of such criteria are the interpretability of results, the ease of the modelling task, data requirements, etc.

Despite the usefulness of geographical accessibility as a concept for evaluating the implications of (policy) interferences in the transport (geographical) system, geographical accessibility indicators, at least as far as the author's knows, have not yet been used explicitly to evaluate road pricing effects. A possible reason may be that geographical accessibility measures cannot be used directly to evaluate road pricing effects without a further tailoring of the indicators. In applied accessibility studies travel time or distance-based accessibility indicators are most often used. To assess accessibility effects as a result of road pricing, however, a transport cost-based accessibility indicator is needed. The financial costs of a (road) pricing measure can be seen as an (extra) resistance to reach a certain destination, next to other elements like travel time. In order to combine different resistance factors a generalized transport cost function may be used. In such a function travel times can be monetarized by using time valuations. The extra toll component can then easily be added. However, using only one generalized transport function may not be sufficient for modelling 'realistic' accessibility effects. The generalized transport cost function for different (groups of) people and firms may differ, and in addition they (i.e. different people and firms) may 'deal' with charging costs in an unequal way. Some types of travellers may decide to change behaviour in order to reduce their costs, which will have an impact on accessibility. Subsequently, all these behavioural adaptations put together may influence travel resistances and the land-use system. Changes in resistances and locations in turn affect accessibility again. Moreover, the implementation of pricing measures may result in monetary gains for decision/policy makers. These 'revenues' may then be reinvested in society in different ways. Such reinvestments can also influence accessibility. Thus, realistic accessibility effects cannot be retrieved by only calculating the financial value of certain resistance components. Considering characteristics of categories/groups of travellers, behavioural processes and revenue reinvestments are important as well.

In modelling the accessibility effects as a result of road pricing several choices have to be made with regard to modelling characteristics. Modellers or decision-makers, for example, have to choose a type of accessibility measure(s), the construction and level of differentiation of the generalized transport cost function and the level of network differentiation to be applied. The choice of such factors influence accessibility outcomes. This makes it important to gain insight into the sensitivity of accessibility outcomes for all kinds of (cost-related and other) characteristics. A high sensitivity for varying a certain attribute, for example, indicates that it is important to carefully operationalize such a characteristic when one wants to model realistic accessibility effects due to pricing measures.

To summarize, the added value of this thesis is that it explores fruitful ways to determine geographical accessibility effects/changes due to road pricing measures. In order to model realistic accessibility effects due to pricing measures it is important to select (a) suitable accessibility measure(s). Subsequently, (b) differences in the characteristics of travellers and behavioural effects must be taken into account. Finally, (c) it is also important to know how sensitive accessibility outcomes are to certain choices and assumptions made by the modeller. Therefore, the first aim of this thesis is:

To provide (more) insight into how to model realistic geographical accessibility effects due to pricing measures by (i) theoretically assessing the choice of suitable accessibility measures, the specification of the resistance function that is needed and the modelling processes to be considered and by (ii) practically determining the sensitivity of the modelled accessibility effects to varying price measure or (other) accessibility measure-related aspects.

The actual long-term geographical effects under influence of transport pricing are the relocation and location choices of actors such as households and firms. As described in section 1.2, these relocation effects can have an impact on the traffic situation, especially in areas facing traffic congestion problems. Furthermore, due to pricing measures, demands for land and houses (in certain areas) may change, affecting land/house prices and ultimately the entire land-use pattern. However, in spite of these potential effects, literature shows that location effects due to or under (road) pricing policies have been studied only in a limited way. Existing studies can be roughly subdivided into more qualitative theoretical or conceptual studies on the one hand, and modelling studies on the other hand (see section 2.7). These studies, however, do not provide a broad insight into the location effects under influence of a range of different transport pricing measures, nor do they focus on the types of people and firms that are more or less likely to adapt their locations. Empirical research can provide such insights. Yet, as far as the author of this thesis is aware, no scientific literature of empirical insights into the relocation effects as a result of pricing exist[6]. In addition, there are few studies that have carried out a systematic examination of the effects of various (road) pricing measures on short-term (car trip) and longer-term (location) behaviour simultaneously.

In spite of the limited research on (re)location choices of households and firms as a result of transport pricing, a broad field of research exists studying the influence of transport-related characteristics, such as travel distance, time (and sometimes travel costs) on residential and work (re)locations of households and on settlement relocations of firms (see section 2.6.3 and 2.6.4). However, although sometimes influences of travel costs are studied, these costs consist of travel costs in general. Transport pricing costs are more directly linked to car usage. In combination with the high resistance against pricing measures this may result in different relocation effects.

Compared to the broad field of research regarding the influence of transport-related characteristics on long-term (re)location choices, there are fewer studies (known to exist) that deal with the influence of transport costs on people's medium-term location-based activities, such as recreation and shopping. Partly this can be explained by the fact that the home-work relationship is at the centre of urban geographical research (see Hanson and Pratt, 1988). Residential locations may have a large influence on job choices and vice versa (see Hanson and Pratt, 1988). Together they determine a large portion of people's daily routines (including choices where to shop, recreate, etc.), which is why this thesis focuses specifically on examining changes in the residential and work location choices of households and settlement locations choices of firms under pricing conditions.

6 One exception in this case is the work of Arentze and Timmermans (2005).

In short, existing literature provides little insight into the location effects of households and firms due to or under influence of various types of transport pricing measures. This is mainly the result of an absence of empirical data. Because of the possible effects of relocation choices on traffic congestion levels and on house prices, and finally to be able to give a complete overview of all, not only short-term behavioural effects, obtainment of insight into these location effects is important. Although this thesis especially focuses on the geographical effects of households and firms, long-term effects must be placed in the light of changes in people's and firm's short-term travel behaviour, as explained in section 1.2. Summing up, this thesis is particularly innovative in the following ways: (i) behavioural effects are studied on basis of empirical data and (ii) both for households and firms; (iii) long-term effects are studied alongside short-term behavioural changes; (iv) the study examines which groups of people and firms are more or less likely to change a certain behaviour due to road pricing and (v) the thesis systematically examines the effects of various road pricing measures on household's location behaviour. All this brings us to the second goal of this thesis:

To provide insight into the behavioural effects, especially (re)location[7] choices of households and firms, due to or under influence of (different) transport pricing measures.

The aim is to gain insight into the behavioural changes/effects, especially the long-term ones, under road pricing conditions. More secondary effects, such as the influence of location changes on housing or land prices and in the end effects of transport pricing on the entire spatial configuration of activity locations (i.e. land-use) are not included in this thesis. In conclusion, there are two central objectives. First of all, to model geographical accessibility (effects) due to (road) pricing, and secondly, the aim is to study the behavioural choices of households and firms due to pricing conditions, especially with regard to (re)location. In the next section these two goals are translated into research questions.

1.4 - Research questions

To be able to reach the goals formulated above, different research questions have to be answered. The research questions related to the 'accessibility' goal are described in section 1.4.1. The second goal is operationalized in section 1.4.2.

1.4.1 - Research questions related to geographical accessibility (goal 1)

Two research questions are formulated in relation to the 'accessibility' goal:

1. *To what extent are current geographical accessibility measures applicable for modelling accessibility effects due to road pricing and which aspects and processes have to be taken into account for modelling realistic accessibility effects due to road pricing?*

The objective here is to assess the suitability of the various types of accessibility indicators for modelling accessibility effects as a result of road pricing conditions. Moreover, behavioural

7 The emphasis is on choices regarding residential and work location in the case of households and settlement locations in case of firms.

mechanisms (i.e. short and long-term changes in behaviour and use of revenues) that have to be taken into account in the modelling process are examined because they influence accessibility changes due to pricing measures.

2. *To what extent are geographical accessibility measure outcomes under road pricing conditions sensitive to varying cost (i.e. type of price measure, price level, specification of generalized transport cost function) and non-cost related aspects (i.e. accessibility measure, resistance parameter and network detail), and what implications for modelling geographical accessibility effects due to road pricing can be derived from these analyses?*

As described in section 1.3, when computing geographical accessibility, modellers must make several choices regarding modelling characteristics. If accessibility outcomes are sensitive to such choices, this makes the process of selecting proper (input) characteristic values a task that requires even more specific attention. In the case of road pricing, cost-related characteristics are important. Therefore, an explicit distinction is made between studying the sensitivity of accessibility outcomes to varying cost, on the one hand, and non-cost related aspects on the other hand. Examples of cost-related aspects that may influence geographical accessibility are: the type of price measure, the height of the charge (i.e. the price level), and the specification of the generalized transport cost function (e.g. the factors taken into account into the resistance function). Non-cost related characteristics are, for example, the choice of the (suitable) accessibility measure and the selected resistance parameter in impedance functions. On the basis of the sensitivities that are observed for various cost and non-cost related aspects implications are derived for modelling the geographical accessibility effects due to (road) pricing measures.

1.4.2 - Research questions related to (long-term) behavioural effects (goal 2)

Two research questions are formulated in relation to the second goal. The first one is:

3. *To what extent do (road) pricing policies influence short-term trip/travel patterns and (re)location, especially work and residential location, choices of households?*

This thesis mainly focuses on studying pricing policy effects from a geographic perspective. Work and residential location choices of households under influence of different road pricing measures are studied extensively, because of the above-mentioned importance of these types of locations in structuring the daily routine of people (see Hanson and Pratt, 1988). Additionally, some insight is provided into daily and non-daily shopping relocations. Shopping locations are included because they may be more 'adaptable' than other types of locations (e.g. residential, work, social/visiting locations).

As described in sections 1.2 and 1.3, long-term effects cannot be analysed thoroughly without having insight into short-term (travel/trip pattern) changes. This is why short-term changes are also studied. Short-term changes are, for example, changes in the mode of transport, departure time, travel frequency, ridesharing, etc.. The changes that occur will depend largely on the type of (road) pricing that is introduced. In total, trip change behaviour is studied for four trip motives: (i) for commuter travel, (ii) social (family visiting) trips, (iii) other than commuter travel or social trips and for (iv) daily and non-daily shopping trips. This fourth category forms a specific case of 'other trips' (i.e. the third motive). A motivation for selecting these four trip motives is provided in sections 3.4.4 and 3.4.5.

4. *To what extent does (road) pricing[8] influence the perceived accessibility and short and long-term behaviour of firms?*

On the one hand, changes in the perceived accessibility of firms due to pricing are studied. On the other hand, short and long-term behavioural changes of firms are examined. Short-term changes are defined as changes in the trip pattern and in ways firms compensate their employees. Travel/trip pattern changes consist, for example, of changes in the frequency and timing of (business and transportation) trips. Moreover, we look at changes in the compensation behaviour of firms towards their employees (for example travel costs or relocation compensations). These changes may in turn influence the behaviour of households. However, this thesis does not examine the link between what firms offer their employees and what households may expect. Finally, firms might decide in the long run to look for another place to locate their business. The objective of this thesis is to gain insight into the probability that particular types of firms will change their location as a result of transport pricing.

1.5 - Outline thesis

This study is organized into eight chapters (see figure 1.1). Chapter 2 is the theoretical chapter. It especially looks at road pricing from a geographical perspective. The chapter does not explicitly describe literature regarding changes in short-term travel patterns due to pricing because the main focus is on the geographical perspective. The geographical perspective is translated into two research themes: geographical accessibility and location choices of households and firms. First, we describe the background of the pricing policies. After that the theoretical link between geographical accessibility and activity locations is described. However, the main part of chapter 2 is devoted to accessibility and location choice theory. With respect to accessibility, the concept is defined, indicators are described, suitable measures for computing accessibility under road pricing conditions are distinguished and finally (first) directions are given for computing realistic geographical accessibility effects due to (road) pricing. This part of chapter 2 addresses the first research question. In addition, the chapter gives insight into evidence from literature regarding the effect of transport (costs)[9] on location choices of households and firms. Finally, the chapter provides a conceptual model linking road pricing, geographical accessibility and the location-related choices of households and firms.

Chapter 3 describes the research design and methods, indicating how each research question is answered. First, the research methods and data required to answer the research questions are described, after which the techniques that are needed to analyse the data are explained.

Chapter 4 studies the sensitivity of accessibility outcomes under road pricing conditions to various cost and non-cost related characteristics and addresses research question 2. Firstly, the sensitivity of accessibility outcomes is studied for varying cost aspects, such as the type of price measure, charge height and the configuration of the generalized transport cost function.

8 Only one pricing measure will be analyzed (see section 3.4.6).

9 The influence of road pricing costs is studied as a special case of transport costs.

This is followed by an analysis of the sensitivity for characteristics that are not only important in computing accessibility effects due to road pricing, but that may also be influential when modelling accessibility effects e.g. due to (the introduction of) other policy measures. Examples of such characteristics are the choice of the type of accessibility measure and the applied detail of the road network in sensitivity analyses. Insight into the sensitivity of accessibility outcomes results in implications for modelling accessibility effects due to (road) pricing measures.

Chapter 5 describes the short-term behavioural changes of households due to different (road) pricing measures and addresses the first part of research question 3. Behavioural changes are described for four trip motives: commuting, social and other trips[10], and daily or non-daily shopping trips (including changes in shopping locations). Moreover, the influence of price

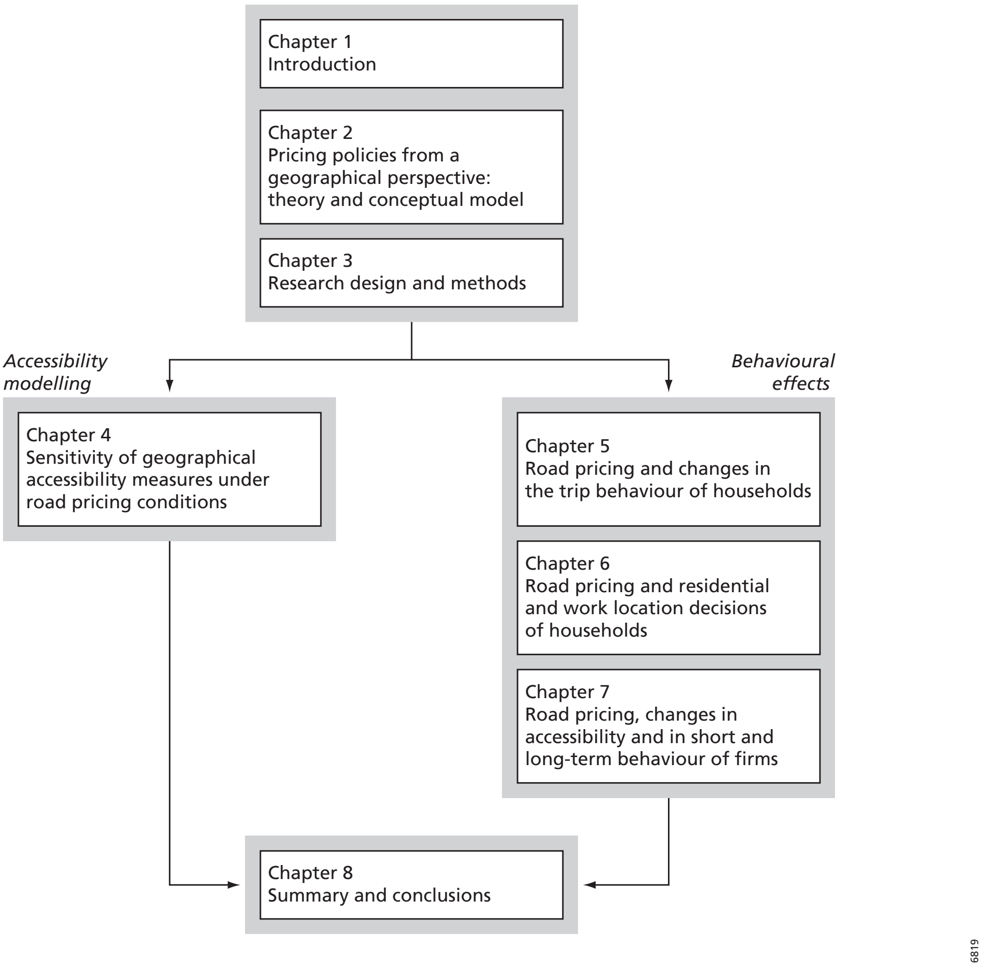

Figure 1.1: outline thesis

10 'Other' trips refer to all remaining trips that do not belong to the categories of 'commuting' or 'social trips'.

measure characteristics (price height and type of revenue use) on people's travel behaviour is examined. Finally, we examine the explanatory socio-economic, demographic and trip related factors to obtain insight into the type of people that are more or less willing to change their travel behaviour as a result of pricing measures.

Chapter 6 addresses the location effects of households due to or under (road) pricing conditions, and addresses the second part of research question 3. First, we look at relocation, providing insight into the extent to which households are intending to change their residential and/or work location as a result of different types of pricing. This is followed by an analysis of explanatory, especially socio-economic and demographic characteristics for relocation (due to pricing). In the second part of the chapter an analysis is presented of the trade-offs households make between several location/house related variables and travel cost and travel time characteristics in residential location decisions. Here, too, the influence of explanatory characteristics is studied.

In contrast to chapters 5 and 6, chapter 7 focuses on firms, addressing research question 4. Firstly, changes in the perceived accessibility of firms due to a road pricing measure are analysed, including the explanatory factors, as well as the short and long-term behavioural changes due to pricing. Short-term changes are merely operationalized as changes in the travel pattern and employee compensation behaviour of firms due to road pricing. Relocations are regarded as long-term changes. An analysis of explanatory factors is presented only for the long-term relocation behaviour. The reason we did not include an analysis of the short-term changes, as we mentioned earlier, is because this thesis focuses specifically on the geographic perspective.

In chapter 8, finally, a summary of the research is presented, alongside the conclusions, policy recommendations and suggestions for future research.

2 - Pricing policies from a geographical perspective: theory and conceptual model

2.1 - Introduction

The introduction of road pricing measures may have an effect on the behaviour of households and firms. In the short-term, households may decide, depending on the type of pricing, to make changes in their travel pattern[11] (e.g. mode choice, departure time, etc.). In the longer-term, road pricing can have an influence on the (re)location decisions of household and firms. This chapter looks at road pricing in particular from a geographical perspective, whereby the geographical perspective is translated into two research themes: geographical accessibility and location choices of households and firms.

Geographical accessibility, explicitly linking traffic network effects to activity locations, can be used as a concept to evaluate the effects of different types of road pricing measures. Traffic can be seen as a derived demand, because the actual demand is determined by the desire to engage in different activities at different places. As such, geographical accessibility as a policy indicator seems to have advantages above more specific transport network-related accessibility indicators, which do not take account of the spatial configuration of activity locations. One of the aims of this chapter is to explain and describe geographical accessibility in greater detail. Moreover, the aim is to assess the extent to which current geographical accessibility measures can be applied to model realistic accessibility effects due to road pricing, and to determine which aspects and processes have to be taken into account to do so (i.e. answering research question 1).

The second part of this chapter focuses on the actual and visible geographical effects of road pricing policies: the (re)location choices of households and firms. With respect to location choices, the aim of this chapter is specifically to provide greater insight into the influence road pricing-related transport costs have on where households and firms decide to locate. Because as yet few studies have examined this area, we have decided to describe literature concerning the influence of general transport (cost) resistance factors on the location choices of households and firms in greater detail. In addition, literature concerning the influence of transport costs on medium-term activity locations, such as recreational and shopping locations, is lacking, which is why it is not discussed. In other words, we specifically focus on describing the effects of transport on the residential and work-related locations of households, and on settlement locations of firms[12].

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11 Possible short-term changes due to road pricing are (dependent on the type of measure) in random order: changes in route choice, departure time, mode of transport and changes in the frequency of travelling (May and Milne, 2000).

12 In addition to changing where they are located, firms may also decide to choose other suppliers or customers (in other locations) as a result of a pricing measure. However, these latter effects are not included in this thesis.

After describing the relationships between road pricing and accessibility on the one hand and road pricing and location choices on the other hand, the final aim of this chapter is to combine both aspects in a conceptual model that shows the relationships between accessibility and location choices and indicates how road pricing influences this system. This conceptual model is used implicitly as a guideline in the remaining chapters when describing results.

More specifically, the outline of this chapter is as follows. Section 2.2 addresses the background of pricing policies. Section 2.3 describes the concept of land-use transport interaction, thereby making clear the relationship between geographical accessibility and physical activity locations. Section 2.4 defines accessibility and contains an overview of accessibility measures and criteria to determine the suitability of these measures for different purposes. Section 2.5 links accessibility and road pricing (i) by determining the suitability of different accessibility measures for modelling (household) accessibility effects due to road pricing and (ii) by providing directions for modelling realistic accessibility effects in the case of road pricing. Sections 2.6 and 2.7 look at the influence of transport (costs) on (re)location choices of households and firms. In particular, section 2.6 describes evidence from literature regarding the link between transport and relocation in general. Section 2.7, on the other hand, offers insight into literature regarding relocation as a result of (road) pricing policies. In section 2.8, a conceptual model is presented regarding the relationships between road pricing, accessibility and location choices. The overall conclusions are presented in section 2.9.

2.2 - Pricing policy: backgrounds

Pricing policy is a popular research topic, especially in the field of economics. This is mainly due to the typical economic aspects, which can be found in the theory of pricing policy, such as the pricing of a scarcity (in this case infrastructure). Since nearly all forms of transport are associated with externalities like congestion and emissions, there has been a great deal of interest in various ways to price these externalities. Among economists a widely accepted benchmark solution in the regulation of road transport externalities is the first-best pricing (i.e. Pigouvian marginal external cost pricing; Pigou, 1920). From an economic point of view first-best pricing can be seen as the most efficient/optimal type of pricing policy, whereby all road users at all times pay exactly what they 'cost' society as a whole. Examples of such external costs are emission costs, congestion costs, etc., caused by trips made by a driver. With first-best pricing it is assumed that optimal charging mechanisms are available, allowing regulators to set perfectly differentiated taxes for all road users and on all links of the network; that first-best conditions prevail throughout the economic environment to which the transport system under consideration belongs; and that all the road users as well as the regulator have perfect information on traffic conditions and tolls at their disposal (see also Verhoef, 1996; Ubbels, 2002). Apart from the fact that these assumptions cause almost unsolvable difficulties in terms of technical implementation[13], they also generate considerable resistance on the part of the actors involved. It is commonly acknowledged that the above-mentioned assumptions will hardly, if ever, be met in a real-life situation, which is why

13 Technical implementation problems are that tolls have to be able to vary constantly in a perfect way such that the external costs can be accounted for in a perfect way. Therefore, tolls have to vary constantly on the basis of traffic intensity, but also on the basis of, for example, the amount of pollution caused by the vehicles.

second-best pricing issues, based on less utopian assumptions, have received ample attention in literature (Verhoef, 2000).

Policy-makers have different design options or 'buttons' with regard to transport pricing measures. Pricing measures can vary on the basis of the price level, the level of differentiation applied, the coverage of the measure, the revenue use and other supplementary policies (Verhoef *et al.*, 2004). Differentiation of the measure can, for example, be based on time, place and/or type of vehicle. With respect to coverage, Verhoef *et al.* (2004) distinguish the following levels (for implementation): single lanes, single roads and different geographical levels, such as local, regional, national or international scales. Furthermore, different categories for revenue use can be distinguished. Revenues can, for example, be used to lower certain taxes, to fund new (or maintain old) infrastructure, to management/control of road infrastructure, or to finance particular (traffic) policies (Verhoef *et al.*, 2004). Due to the different design options numerous pricing alternatives can (in theory) be designed.

Some practical and well-known examples of transport (road) pricing measures are the various types of cordon or toll charges, kilometre measures, congestion or road pricing schemes and toll/pay lanes/roads. In case of cordon charges, travellers have to pay a toll when they pass a certain checkpoint (or toll portal). Cordon charges can be implemented in cities in such a way that car drivers have to pay when they enter and/or leave a city (centre). A specific feature is that drivers only have to pay at a certain fixed point(s). A kilometre charge, on the other hand, is less instantaneous. People pay for every kilometre they drive. Subsequently, congestion (or road) pricing measures try to offer people incentives to drive at other times or via other routes, with the final aim of alleviating congestion problems at certain locations and time periods. Finally, in the case of toll lanes or toll roads, people only have to pay for driving on a particular lane or road. These pay or toll lanes can also be differentiated based on time or traffic intensity.

The importance of pricing policies can be deduced from the fact that an increasing number of road pricing projects are and have been implemented in various countries around the world, for example in Norway (see: Hårsman, 2001; Odeck and Bråthen, 1997), Singapore (see Phang and Toh, 1997) and Hong Kong, the toll-lanes in the United States (see, for example, Golob, 2001) and the freight kilometre charge in Germany (toll-collect, 2005). However, the most striking example is probably the congestion charge scheme in London (TfL, 2003). In addition to schemes that have already been implemented, some cities (e.g. Edinburgh; see Rye, 2005) or countries (e.g. the Netherlands; see e.g. CPB, 1998; Nationaal platform anders betalen voor mobiliteit, 2005; Verhoef *et al.*, 2004) are planning or had planned some form of pricing, without thus far proceeding to the actual implementation for various reasons, some of which are related to the level of acceptance (see Verhoef *et al.*, 1995; Rienstra *et al.*, 1999; Verhoef *et al.*, 2004).

We want to point here that internalising all of the external costs is not the sole objective of the majority of pricing policy projects. The reason for introducing toll pricing in Norway, for example, was to finance infrastructure costs, whereas in Singapore and London the intention was to bring about a reduction in traffic congestion (which is only one aspect of external costs). Furthermore, the kilometre charge in Germany is aimed at generating revenues in general. Thus, although different pricing measures[14] have been implemented or proposed, in most cases the type of measures are different and have a variety of objectives, ranging from generating revenues in general and financing infrastructure, to explicitly internalizing (some of the) external traffic-related costs.

2.3 - Land-use transport interaction

2.3.1 - Criteria to measure the suitability of measures

People travel because they want to engage in certain activities that are located at different locations (Van Wee, 2002). Some examples of activities are working, shopping, recreating, visiting relatives or friends, going to movies or theatres, etc. Goods are transported because they have to be manufactured into products in one place and sold to customers as 'end-products' somewhere else (see Van Wee and Dijst, 2002). Traffic can therefore be seen as a derived demand. The actual demand is determined by people's desire or need to engage in activities at different places. This means that land-use patterns (the spatial configuration of activities) would appear to have what is potentially a major impact on transport. Understanding the influence of land-use on transport would make it possible to develop certain land-use policies, such as policies aiming at reducing the congestion problems that are characteristic of many urbanised areas in the world. However, after years of research and political debate there still is no real consensus regarding the relationship between land-use and transport.

Although the land-use configuration may have an important effect on the generation, distribution and mode of travel, the opposite may also be true: location choices of firms and the choice of work and residential locations of households are partly based on transport (costs). There seems to be a mutual interaction: transport influences the land-use pattern and in turn the land-use pattern influences the demand for travel. This has led to the notion of the 'land-use transport feedback cycle' (see Figure 2.1). The set of relationships implied by this concept can be summarized as follows:

- The distribution of land-uses, such as residential, industrial or commercial, over the urban area determines where human activities such as living, working, shopping, education or leisure are located.

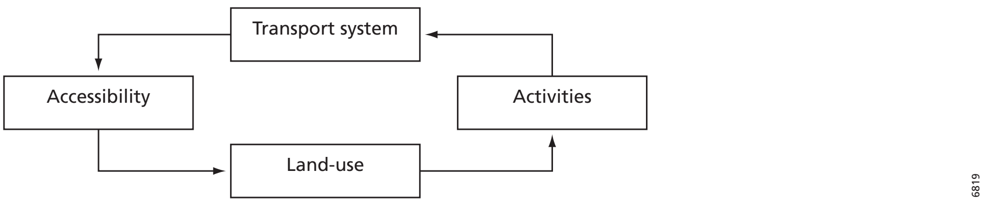

Figure 2.1: land-use transport feedback cycle (source: Wegener and Fürst, 1999)

14 For an overview of various forms and categories of road pricing (policies), see Geurs and Van Wee (1997), Van Wee (1995) and Victoria Transport Policy Institute (2001).

- The distribution of human activities in space requires people to move from one place to another, using the available transport system to overcome the distance between locations of activities.
- The distribution of infrastructure in the transport system creates opportunities for spatial interactions and can be measured as accessibility.
- The distribution of accessibility in space co-determines location decisions and thus results in changes of the land-use system[15] (Wegener and Fürst, 1999).

2.3.2 - Effect of land-use on transport

The effect of land-use on transport has been studied extensively (see, for example, Mackett, 1993; Kitamura and Mokhtarian, 1997; Wegener and Fürst, 1999; Bagley and Mokhtarian, 2002; Schwanen, 2002; Van Wee, 2002; Giuliano and Dargay, 2006). In general, there seems to be sufficient scientific evidence to indicate that land-use influences travel behaviour at various geographical scales (Van Wee, 2002). On the basis of a literature review, Wegener and Fürst (1999) sum up some of the major findings, indicating that the impact of high residential density in reducing average trip length, without travel cost increases, is likely to be minimal, whereas high employment density has a positive relationship to trip length. Moreover, attractive neighbourhood facilities and a larger city size in general seem to lead to reductions in average trip length. With regard to trip frequency, however, Wegener and Fürst (1999) find that land-use policies have little or no impact. Residential and employment density, as well as agglomeration size and public transport accessibility, seem to be positively related to modal share of public transport. Finally, Wegener and Fürst conclude that the design of a neighbourhood and having a mixture of workplaces and residences with shorter trips seem to have a positive influence on walking and cycling shares. Other overviews can be found, for example, in Handy (1996), Van Wee (2002) and Meurs (2003). In general, the results of their reviews correspond to those presented here. Having said that, there is still some uncertainty as to what the exact effects are of land-use on transport (see Van Wee, 2002).

Literature on the influence of land-use on transport characteristics can roughly be categorized on the basis of the geographical and/or methodological scale. Different spatial scales can be distinguished: from the individual buildings and neighbourhoods, cities and regions, to the national and international scale. The issues that are addressed and the indicators that are used vary between studies falling within those different spatial scales (Meurs and Van Wee, 2003). At a low spatial scale (i.e. building level) the availability of a garage or a garden may, for example, affect which mode of transport people will select (see, for example, Meurs and Haaijer, 2001): people may find it easier to take the bike than first having to open the garage door if all they want to do is some quick shopping. Also, if there is a good and separate cycle path available, people may be more willing to opt in favour of the bicycle than if that is not the case. An example of land-use characteristics at city or regional level is the spatial distribution of population (or infrastructure) density. And, finally, at a national level, the geographical position of (networks of) cities relative to each other can be seen as an example. Meurs and Van Wee (2003) state that a large number

15 Urban form is a broader concept than the more commonly used 'land-use'; land-use patterns are one aspect of urban form, which also encompasses characteristics of the transportation system and urban design features more generally. Urban form is thus a composite of a multitude of characteristics (Handy, 1996).

of empirical studies are available at the level of regions, cities and neighbourhoods, but that less attention has been paid to the national and international levels.

Another possible categorization is the one based on the methodology of analysis used. According to Handy (1996), most of the research on the relationship between urban form and travel behaviour falls into three categories: aggregate analyses, disaggregate analyses[16] and simulation models. Aggregate types of studies characterize both urban form and travel for cities, neighbourhoods or zones using aggregate measures to test the strength of the relationship using simple comparisons, correlations, or regression procedures (Handy, 1996). The approach has provided evidence on the strength of the relationships between land-use and transport. Nevertheless, the aggregate methodology does not allow for an exploration of the underlying factors and mechanisms by which urban form influences people's individual decisions (Handy, 1996). In contrast to aggregate analyses, disaggregate analyses use individual and household socio-economic and travel characteristics rather than zone-related averages, and as such are aimed more at explaining relationships. Finally, the third research methodology uses model simulation studies to forecast the effects of land-use (policy measures) on transport-related characteristics (see, for example, Schoemakers and Van der Hoorn, 2004).

There are several methodological issues that may be relevant to future research regarding the impact of land-use on transport (see, for example, Handy, 1996; Van Wee, 2002; Meurs and Van Wee, 2003). Handy (1996) argues that it is important to determine how certain urban characteristics influence transport; for example assessing which urban characteristics influence what kind of trips. She also recommends developing uniform indicators[17]. This may improve comparability between studies and make it clear to respondents what researchers mean. Another commonly acknowledged improvement to land-use transport impact studies has to do with explicitly incorporating the effect of self-selection in their analyses (see Handy, 1996; Meurs and Van Wee, 2003). The effects of land-use on transport may be lower when self-selection effects are taken into account. For example, if we assume that researchers find that within an area that has a dense public transport infrastructure car use is lower than in an area with a low-density public transport network, does that mean that the land-use structure (i.e. dense public transport network) has led to a lower share of car trips, or are the residents living in such an area more fond of using public transport and have they moved to that area precisely because of the public transport facilities (i.e. self-selection)? Thus, to be able to study the effects of land-use on transport thoroughly, it is important to take these self-selection effects on board. Next to self-selection, the importance of taking socio-economic and demographic factors into account in land-use – transport analyses is commonly acknowledged. To examine these more individual effects properly, multivariate models are required (Meurs and Van Wee, 2003). Studies that already have included individual or household characteristics have shown that these characteristics generally speaking are more explanatory for transport behaviour than land-use features (see, for example, Meurs and Haaijer, 2001; Schwanen, 2002). However, even within 'homogeneous' groups there are differences in behaviour. Therefore, attitudes and perceptions of individuals ideally have to

16 To an extent the categorizations based on geographical scale and on aggregate or disaggregate data are linked. Studying effects on a lower spatial scale, for example, demands a higher level of detail of the data.

17 In addition, Van Wee (2002) proposes looking at a wider range of indicators than is done in current studies, taking into account effects of land-use policies on externalities such as noise and air pollution as well.

be incorporated as well when analyzing the influence of land-use on transport (Handy, 1996). Some studies looked at the influence of these factors, such as Kitamura and Mokhtarian (1997), Bagley and Mokhtarian (2002) and Schwanen and Mokhtarian (2005). In general they found that attitudes and perceptions are important explanatory factors in transport-related choices, which reduces the direct influence of land-use on transport. However, indirect relationships of land-use on transport (i.e. via attitude, life style and or individual characteristics) may still be present. Therefore, it is important to assess the direct as well as indirect effects when analysing links between land-use and transport (Meurs and Van Wee, 2003).

Another methodological issue for future consideration is the influence of dynamics. More short-term and long-term evaluations of the effects of land-use policies and infrastructure development are needed (Meurs and Van Wee, 2003), because the effects may vary according to the time scale for (or in) which effects are studied. Researching these dynamics, however, requires the use of longitudinal data (see also Meurs and Haaijer, 2001 for an application). In addition, the existence of travel time budgets has to be taken into account. People may not react to transport costs as being a continuous variable, but instead decide to change their behaviour when a certain threshold has been crossed. Thus, people may behave in a more discrete way. Traditional analyses that do not take these travel time budgets into account could overestimate the variation in travel behaviour between land-use and other scenarios. A final point we want to mention here is that Van Wee (2002) recommends studying the effects of combined determinants instead of studying the effects separately. This will make it possible to take the combined alternatives that are available to people into account. For example, the impact of densities on travel behaviour may be larger if high-density locations are near a railway station.

Several of these methodological recommendations may also be important when studying road pricing effects. Insight into the location effects as a result of pricing measures can, for example, be improved by incorporating, next to land-use characteristics, socio-economic/demographic factors and even attitudes and perceptions into analyses. This provides insight into the types of people and firms that are specifically changing their behaviour (in a certain way). Moreover, it may be useful to consider self-selection effects when analysing results. However, although some of the above-mentioned issues are worthwhile considering when examining road pricing results, the geographic effects due to pricing are not directly related to studying the influence of land-use on transport. It is rather the other way around, as we describe in section 2.3.2: road pricing (i.e. transport) influences land-use.

2.3.3 - Effect of transport on land-use: the specific case of (road) pricing

Although the impact of land-use on transport has been studied thoroughly, the inverse impact (i.e. influence transport on land-use) has attracted much less attention from empirical researchers (see also section 2.6). According to Wegener and Fürst (1999) this may be explained by the fact that land-uses change much more slowly than travel behaviour and are subject to other influences than transport (for example population growth, economic development, changes in life styles, household formation, consumption patterns and production technology), which makes it difficult to isolate effects. However, looking at the effects of road pricing from a geographical perspective, especially the influence of transport on accessibility and (re)location choices of households and firms is important. The introduction of road pricing measures affects the transport costs of a road network (at specific locations and/or different points in time), and hence (see also figure 2.1) has an immediate impact on the transport system. Changes in the transport system in turn affect the accessibility of activity locations.

Accessibility is an important concept linking the transport system to the land-use system: it takes characteristics of both the transport system (i.e. travel impedances) and the land-use system (location of activity locations) into account. However, this intermediate role also makes it hard to understand accessibility. It is a somewhat theoretic concept that does not exist in the 'real' world. The transport (e.g. roads) and land-use (activity locations) system, by contrast, are more tangible; everybody can observe changes in these systems. In practice accessibility is mostly used as an intermediate phase in land-use transport modelling, in which the final aim is to forecast changes in the land-use or transport system as a result of changes in one or more of these systems. Nevertheless, accessibility can also be used as a research indicator in itself. Accessibility indicators or measures offer a quick insight into the (accessibility) effects of changes in the land-use or transport system, because they are relatively easy to interpret and their outcomes can be computed quickly. By contrast land-use transport models are sophisticated, and the modelling process involved is less transparent. Calibrating those detailed models for a particular study area of interest is time-consuming and requires many data. Thus, accessibility can be used as a concept to obtain insight into the effects of land-use and/or transport changes on the activity patterns of people in an easy and transparent way. Therefore, accessibility (indicators) is also a useful tool for making policy assessments, for example in relation to road pricing effects.

In contrast to the role of accessibility as a theoretical modelling concept that can be used for assessing the impact of traffic policies (for example road pricing), (re)location choices form the visible geographical effects (see figure 2.1). Households and/or firms can decide to relocate specifically due to road pricing. On the other hand, road pricing may also influence decisions where to settle even when the decision to relocate has been made initially for other reasons. (Re)location choices in turn may also have consequences for travel circumstances in the sense that trip patterns (e.g. making trips less often) will change and mode changes may occur (e.g. choose another transport mode in case the relocation changed the commuting distance). These changes may ultimately affect traffic densities and congestion on particular parts of the transportation network. In general two types of (re)location effects can be distinguished: medium and long(er) term relocations. Examples of medium-term location effects are people's choices of shopping and recreational locations. Work and residential (re)locations are examples of longer-term effects. For a more detailed description of the relationships between road pricing, accessibility and location choices, see section 2.8.

After describing the concept of land-use transport interaction, we now focus in more detail on the relationship between road pricing and geographical accessibility on the one hand, and between transport costs (and road pricing) and location choices of households and firms on the other. The next section looks specifically at the concept of accessibility and provides directions for applying accessibility measures as a modelling tool for analysing accessibility effects as a result of road pricing.

2.4 - Geographical accessibility

2.4.1 - Introduction

In this section we work out the concept of geographical accessibility. Section 2.4.2 defines geographical accessibility and provides an overview of existing geographical accessibility measures. In section 2.4.3, criteria are formulated on the basis of which the suitability of various accessibility measures for different purposes can be determined.

2.4.2 - Definition and accessibility measures: an overview

Accessibility plays an important role in transport (geography). In spite of its importance no unambiguous definition of accessibility can be found in literature. Many scientific articles concerned with accessibility, for example, refer to a quote from Gould (1969) (see, for example, Ingram, 1971; Moseley 1979; Huigen, 1986; De Jong and Ritsema van Eck, 1996):

"Accessibility… is a slippery notion… one of those common terms everyone uses until faced with the problem of defining and measuring it."

Geurs and Van Wee (2004) identify four components that are theoretically important in measuring accessibility:

- The land-use component
- The transportation component
- The temporal component
- The individual component

The land-use system consists of (a) the amount, quality and spatial distribution of opportunities supplied at a destination, (b) the demand for these opportunities at origin locations and (c) bringing together supply and demand for opportunities. The transportation component describes the transport system. The temporal component reflects possible temporal constraints caused by people's time schedule and the availability of opportunities at different times of the day. The individual component reflects the needs, abilities and opportunities of individuals. Focusing on passenger transport, Geurs and Van Wee (2004) define accessibility as the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations by means of a (combination of) transport mode(s). The English language literature also uses the word 'access' (see e.g. Dijst, 1995; Geurs, 2006). Although accessibility and access are often used indiscriminately, formally speaking access has to be used when talking about a person's perspective (e.g. how many locations can a person access in a certain time), whereas accessibility generally speaking refers to a location perspective (Geurs, 2006). In the rest of this thesis we will use the term 'accessibility' even when 'access' might be more appropriate, for three reasons: (i) the reader does not constantly have to remember the difference between the two concepts; (ii) the concept of accessibility in (Dutch) practice is most often used also for situations referring to access; (iii) accessibility can be determined by accessibility measures; to the author's knowledge the term 'access measures' is not (commonly) used.

As indicated above, accessibility can be measured/operationalized by using accessibility measures. These measures have been categorized in different (albeit quite similar) ways (see, for example, Geurs and Ritsema van Eck, 2001; Van Wee *et al.*, 2001; Hagoort, 1999; Bruinsma and Rietveld, 1998; Handy and Niemeier, 1997). A more recent categorization, building on earlier classifications, is given by Geurs and Van Wee (2004). They distinguish four basic perspectives on measuring accessibility:

- Infrastructure-based measures
- Location-based measures
- Person-based measures
- Utility-based measures

Infrastructure-based measures, analysing traffic network performance, are used in particular in transport planning. They do not contain a spatial component. They can be regarded as indicators in traffic and transportation research. The impedance component can sometimes be seen as accessibility in itself. Travel time on a link, for example, is an indicator of resistance on that link. Other examples of these types of measures are congestion severity and operating speed on a road network.

Location-based measures take both a transport component and a location component into account. These indicators are typically used for macro-level analyses. Geurs and Van Wee (2004) distinguish four types of location-based measures: contour measures, potential measures, adapted potential measures and balancing factors. Contour and potential measures are quite well known and often used measures in transport geography. A contour measure counts the number of opportunities which can be reached within a given travel time, distance or cost (fixed cost), or is a measure of the (average or total) time or cost required to access a fixed number of opportunities (fixed opportunities). Potential measures (also called gravity-based measures), on the other hand, estimate the accessibility of zone *i* to all other zones (*n*) in which smaller and/or more distant opportunities provide diminishing influences. The measure has the following form:

$$A_i = \sum_j D_j F(c_{ij}) \qquad [2.1]$$

Where A_i is a measure of accessibility in zone i to all opportunities D in zone j and $F(c_{ij})$ is the impedance function, in which c_{ij} represents the costs/resistance to travel between i and j. The cost/impedance function has a significant influence on the results of the accessibility measure and can take on different forms, for example a power or exponential form (see Geurs and Ritsema van Eck, 2001).

'Standard' potential measures (see also Geertman and Ritsema van Eck, 1995) are aggregate (group) measures that do not take individual competition on opportunities into account. The same goes for contour measures. This means that each opportunity at a certain level of resistance is equally important for all people, whereas in reality some opportunities may only be suitable for some individuals[18]. Moreover, when a person engages in a certain activity, that activity may no longer available to others[19]. Some research has been undertaken to take such 'competition' effects (to a certain extent) into account. Geurs and Van Wee (2004) call these types of measures 'adapted potential measures'.

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18 For example, not all people are equally qualified for all jobs located in a certain area.

19 If a person, for example, is hired by a company to do a specific job, that job is no longer available to someone else.

A final category of location-based measures is based on the 'balancing factors' of Wilson's constrained spatial interaction models (Wilson, 1971). The balancing factors ensure either that the magnitude of flows (e.g. trips) originating at zone *i* equals the number of activities in zone *i* (e.g. workers) or that the magnitude of flows (e.g. trips) destined at zone *j* equals the number of activities in zone *j* (e.g. jobs). The balancing factors of this model can be interpreted as relative accessibility measures, modified to account for competition.

Person-based accessibility measures analyse accessibility at a more individual level. Person-based accessibility measures are founded in the space-time geography of Hägerstrand (Hägerstrand, 1970; Dijst, 1995; Dijst, 2006; Schwanen, 2006). The measures analyse accessibility from the viewpoint of the individual, taking individual time and space constraints into account (see Burns, 1979; Kwan, 1998 for applications of this type of measure). So called space-time prisms are used to show the potential areas or opportunities that can be reached given the individual constraints.

Utility-based measures (see e.g. Martínez, 1995) find their origin in economic studies. They measure the economic benefits people derive from having access to spatially distributed activities. All utility-based measures interpret accessibility as the outcome of a set of transport choices. Geurs and Van Wee (2004) distinguish different types of utility-based measures: the logsum benefit measure and the balancing factor benefit measure. The logsum serves as a summary measure, indicating the desirability of the full choice set. The measure is based on the denominator of the multinomial logit model. More recently, Dong *et al.* (2006) developed the activity-based accessibility measure (ABA), which is related to the logsum accessibility measures. The key difference is that it is generated not by examining a particular trip, but by examining all trips and activities throughout the day.

In conclusion, accessibility can be computed by using accessibility measures. Four types of accessibility measures were distinguished and described: infrastructure-based, location-based, person-based and finally utility-based measures. The suitability of these types of measures in general and in the specific case of road pricing has not yet been discussed. Therefore, in section 2.4.3 we describe criteria on the basis of which this suitability can be assessed.

2.4.3 - Criteria to measure suitability of measures

Geurs and Van Wee (2004) have identified five criteria on the basis of which they review the suitability of accessibility measures. These criteria are:

- Theoretical basis
- Operationalisation
- Interpretability and communicability
- Accessibility as a social indicator
- Accessibility as an economic indicator

From a theoretical point of view an ideal measure with respect to land-use and transport should take all of the four components mentioned in section 2.4.2 into account: the land-use, transportation, temporal and individual component. However, which components have to be considered to a large extent depends on the purpose for which the measures are used. For some situations, in which for example the researchers/decision makers are only interested in the level of congestion on specific roads or networks, it is not necessary to take the land-use component into account. On the other hand, when one is interested in what the geographical accessibility effects due to pricing conditions are, the land-use component may be extremely important. Thus, the formulation of an ideal measure depends on the aim for which it is used. Applying the full set of criteria would imply a level of complexity and detail that can probably never be achieved in practice.

The second criterion, operationalisation, represents the ease with which a measure can be used in practice, for example, in ascertaining the availability of data, models and techniques, and time and budget. This criterion will usually be in conflict with one or more of the theoretical criteria. Furthermore, the interpretability and communicability (i.e. third criterion) implies that researchers and policy-makers are able to understand and interpret the measure, and the fourth criterion indicates that accessibility measures can be used as a social indicator if they show the availability of social and economic opportunities of individuals (or groups of individuals). The final criterion refers to the suitability of an accessibility measure as economic indicator. Measures suited for economic analyses should be able to take economic impacts into account. In the first place there are *direct economic benefits*. These are the economic costs and benefits directly related to a project. In the second place *indirect economic benefits* exist, indicating the (wider) economic benefits not directly related to the project but resulting from indirect effects.

As stated above, it is almost impossible to create an accessibility measure that performs well on all criteria. The specific characteristics of a study for which accessibility effects have to be computed determines the best-suited accessibility measure(s). Looking at geographical accessibility effects of a road pricing measure, some more specific criteria are considered important. These more tailored criteria, which again match the framework presented by Geurs and Van Wee, are:

- Realistic outcomes: *theoretical basis, social and economic indicator*
- To be able to model on a regional scale: *operationalisation*
- Relatively low data requirements: *operationalisation*
- Method can be easily transferred to different regions: *operationalisation*
- Easy to interpret (and policy relevant): *interpretability, communicability*

These aspects are to a certain extent mutually interdependent. An easy applicable method for example will quite likely also mean that data requirements are relatively low. Moreover, there may be some tension between different aspects. A method that is easy to apply, for example, often affects the realism of the outcome. Overall, the five aspects can be formulated into one sentence as 'modelling clearly interpretable and realistic (regional) geographic accessibility effects due to road pricing measures against low costs (meaning not only real costs but also effort-related costs)'.

The *realistic outcomes* criterion can be regarded as mix of the following criteria by Geurs and Van Wee (2004): the theoretical basis and the usability (which is, for example, relevant) in social and economic evaluations. The theoretical basis points to the factors an ideal accessibility measure should take into account. The assumed derived effect is that by incorporating important theoretical aspects, the realism of the outcomes increases. Furthermore, to derive realistic outcomes well-suited accessibility measures for road pricing research should include economic and/or social aspects: the accessibility of different individual agents will likely be influenced differently due to the introduction of road pricing. People with a higher incomes, for example, may experience another accessibility change due to pricing than people with lower incomes. Thus, the ability for measures to differentiate according to economic and social aspects is important. The criterion of realistic outcomes is, however, not only of importance in modelling the accessibility effects due to road pricing. It is vital for all modelling studies. If it were not, modelling processes are useless. However, it is hard to determine how realistic a simulation result is in advance; simulation tools are used for prediction. The only way realism can be tested is by calibrating and verifying a model. Accessibility outcomes (under road pricing conditions) computed with accessibility indicators can, for example, be compared to (perceived) accessibility under road pricing derived from empirical research.

The second criterion is the *spatial scale of analysis*, which can be seen as an operationalisation criterion. Currently proposed road pricing measures in the Netherlands are aimed at a nation-wide implementation (see Nationaal Platform anders betalen voor mobiliteit over de weg, 2005). However, from a geographical perspective it may (at least in the Netherlands) be more interesting to study accessibility effects at a regional level than at a national level. Firstly, this is true because congestion problems in general only occur in certain parts/regions of a country. In such regions certain travel time benefits are to be expected. In that respect it is the Western and Southern parts of the Netherlands that are interesting. In regions without congestion, on the other hand, road pricing is quite likely to lead to higher overall (generalized) travel costs. Studying the extent of the reduction in accessibility, already knowing that it is going to fall may be less interesting than studying accessibility outcomes for situations where accessibility benefits due to a certain measure may occur as well. Secondly, and to some extent related to the first point, is the fact that most car travel has a regional rather than a national character. Commuters, for example, tend to stay within a region rather than go cross-country. This makes studying accessibility effects at a regional scale more interesting. Thirdly, computing accessibility at a national level will lead to higher computational demands if the same level of detail is to be maintained. Especially for larger countries this may lead to computational problems. For some specific purposes (e.g. examination of effects of a toll road) more locally oriented accessibility studies may be necessary as well. However, in those kinds of situations *data requirements* (operationalisation criterion) may increase: more specific local information is required, which is in most cases is harder to collect. And more importantly, on that level of detail information is mostly not available at a national level within a single data set. This makes operationalisation harder. Of course, ultimately the preferred level of analysis depends to a large on the organisation/institution that is interested in outcomes. In practice these may quite well be public institutions at a provincial or national level, in which case a choice in favour of a regional (or supra-regional) level of analysis seems obvious.

In addition to the spatial scale, *the ease of transferability* is another criterion that has to be taken into account. It is preferable that the accessibility 'procedure' be general applicable to different regions of interest, without having to collect a substantial amount of new data. This saves costs and makes it easy to compare the accessibility effects across regions. Finally, the *interpretability* of the outcomes is important. Both experts and non-experts must be able to understand and interpret the results quickly in order to make the correct decisions based on the results.

In the next section we evaluate the suitability of different accessibility measures for modelling the accessibility effects as a result of pricing. In addition, the section examines the level of tailoring of the accessibility measures that is required and discusses the processes that have to be taken into account for the determination of realistic accessibility effects due to (road) pricing.

2.5 - Accessibility measures and road pricing

2.5.1 - Introduction

This section links accessibility (measures) to road pricing. The suitability of different accessibility measures for computing the effects of road pricing is described in section 2.5.2. Section 2.5.3 formulates the various aspects that have to be taken into consideration when modelling the accessibility effects as a result of (road) pricing measures.

2.5.2 - Suitability of accessibility measures in case of road pricing

The first category of measures distinguished in section 2.4.2 was that of infrastructure-based measures. An advantage of these types of measures is that the data and (transport) models required to compute the effects are often readily available (i.e. criterion of operationalisation). In addition, the transparency of the measures makes them easy to interpret for both researchers and policy-makers. The measure does, however, not take the land-use component into account; the resistance component is the measure itself. The measure is also not capable of dealing with temporal constraints and individual characteristics. Because it does not incorporate a land-use component it falls outside the scope of this research, which is aimed at 'geographical' accessibility.

Table 2.1 provides an overview of the suitability of the accessibility measures in case of road pricing that are not infrastructure-based. Three location-based measures are distinguished. Contour measures, as a first class, score high on operationalisation, communicability and interpretability. They are relatively undemanding in terms of data and are easy to interpret for researchers as well as policy-makers (see also Bertolini *et al.*, 2005). All these qualities make them particularly well-suited for analyses at regional and supra-regional levels. Moreover, the measures can be applied to different 'regional' study areas, without substantial additional data requirements. The contour measure, therefore, meets four of the five criteria that are considered important in modelling the accessibility effects caused by road pricing. Nevertheless, the measure does not directly meet the requirement of producing realistic outcomes; it lacks most of the theoretical criteria listed above. Contour measures, for example, usually do not take competition effects into account (for an exception, see the application of pressure maps and the proximity count in competition by Ritsema van Eck and De Jong, 1999). This is a disadvantage in modelling accessibility. Furthermore, the measure has a 'discrete' resistance. The modeller determines beforehand what the boundary resistance within the analysis will be. For example, the modeller may decide to determine the number of jobs that can be reached within 15 minutes by car. In this situation 15 minutes can be regarded as the 'boundary' resistance. A possible disadvantage of such a discrete impedance is that all opportunities within a certain resistance boundary are assumed to be equally desirable to all people, whereas in reality different people may value resistance and therefore accessibility differently. In principle, this 'problem' can be mitigated by disaggregating to a more individual-based level of analysis. However, this once again increases the data requirements. Moreover, the resistance component suffers from the arbitrary selection of the isochrone of interest (Ben-Akiva and Lerman, 1985; Geurs and Van Wee, 2004; Bertolini *et al.*, 2005), leading to a lack of differentiation between opportunities adjacent to the origin (e.g.

5 minutes) and those just within the isochrone of interest (e.g. 15 minutes). We can determine how 'serious' this lack of differentiation is for each accessibility study by carrying out sensitivity analyses. However, such a fixed impedance step does not have to be a problem in itself. Decision-makers often use such fixed boundaries in their policies. Policy-makers can, for example, demand that every person in a certain country must be able to reach a hospital within 15 minutes by car.

In light of the 'theoretical' disadvantages mentioned above, the question is whether the conclusion is justified that that contour measures are not suited for accessibility modelling under road pricing conditions. The disadvantages merely refer to using the contour measure as such. However, the measure still is often used in (practical) accessibility analyses. With regard to road pricing, it is important that the accessibility measures can take the costs of road pricing as well as preferences and/or perceptions of (groups of) individuals into account. Although in practice travel times and/or distances are the most commonly used impedance units, travel costs could be used too: the fact that travel costs are not used as an impedance unit does not mean that the contour measure cannot 'handle' costs. The resistance boundary being used (isochrone of interest), for example, may also be expressed in costs (e.g. not looking at the number of possible destination opportunities that can be reached within 30 minutes, but, for example, the destinations that can be reached for up to € 5 of travel cost) (see also Bertolini *et al.*, 2005).

In addition, different (groups of) people may perceive/feel the effects of road pricing differently, which may also influence their accessibility under pricing conditions. As indicated above, contour measures in their 'basic' form do not differentiate for different characteristics of people. Again this does not imply that it is impossible to do so. Using a cost-based resistance function and extending this function with important characteristics and/or preferences can mitigate some of the theoretical 'shortcomings'. In that case two possible theoretical shortcomings remain: the problem of the 'isochrone of interest' and the problem of not taking competition effects into consideration. The first problem cannot be solved without completely altering the measure; the use of isochrones is a typical feature of contour measures. The second problem, i.e. that of the competition effects, in itself is a serious drawback in modelling accessibility effects in general. Nevertheless, the aim of this thesis is not to construct the 'best' accessibility measure, but to see if and how (realistic) accessibility effects due to road pricing can be computed using existing accessibility measures.

Table 2.1: Summary of suitability of different accessibility measures on criteria (in case of road pricing)

Accessibility measure	**Criteria**				
	Realism outcomes	**Ability to model on a regional scale**	**Data requirements**	**Transferability modelling approach to different regions**	**Interpretability + communicability**
Location-based measures					
• Contour measure	-/(+/-)	+	+	+	+
• Potential measure	+/-	+	+	+	+/-
• Balancing factors	+/-	+	+	+	-
Person-based measures	+	+/-	-	-	+/-
Utility-based measures	+	+/-	+/-	+/-	+/-

To conclude, we can state that contour measures cannot be used directly to model accessibility under pricing conditions in the way that they are commonly used. However, when we take travel costs and accessibility-influencing personal characteristics into account, the outcomes of the model will become considerably more realistic. This type of measure should, therefore, not be excluded when modelling accessibility under road pricing conditions in a realistic way.

Potential measures are a second important category of location-based indicators. Looking first at the criteria that are assumed to be important in modelling accessibility under road pricing conditions, the potential measures meets at least the following criteria: modelling at a regional scale, relatively low data requirements and the method is easy transferable to other regions. The measure in general needs the same type/level of input data as contour measures. Nevertheless, some theoretical shortcomings of the contour measure are mitigated. First of all, potential measures already incorporate assumptions regarding people's perceptions of transport by using a (distance) decay function. The resistance function of potential measures consists of a chosen resistance component itself and a distance decay or sensitivity parameter. The higher the decay parameter, the more sensitive people are to a certain resistance. In spite of the benefits a decay parameter offers, practical (aggregate) studies regularly use an arbitrary[20] resistance/decay parameter while the choice of the parameter in fact should be based on empirical data.

Different people may 'value' resistance differently, a phenomenon that can be taken on board by differentiating the decay/resistance parameter. It is, however, not necessary to try to include important personal preferences into resistance parameters only. The cost function itself can also be tailored towards important (personal) characteristics. Including such characteristics may make the accessibility outcomes more realistic. This type of differentiation is comparable to the adaptation of the resistance component of contour measures we described earlier.

Another possible advantage of potential measures is the characteristic of the decay function itself. The resistance function is a continuous (decreasing) function, which solves the problem of the 'isochrone of interest' characteristic of contour measures. However, this does not always have to be an advantage. As discussed above, decision-makers or policy-makers may even want to use such fixed impedance steps (isochrones) as the 'norm' in their policy (e.g. an ambulance must be able to reach every individual within 15 minutes). Finally, an advantage of potential measures above contour measures is that potential measures evaluate the combined effect of land-use and transport elements. This has to do with the nature of the measures themselves, in which opportunities are divided by the resistance to get there.

The potential measure has some disadvantages as well. The 'standard' potential measure does not take competition effects into account, but already some attempts have been made to improve this (see e.g. Van Wee *et al.*, 2001). Moreover, in most practical studies costs are not considered

20 Often a linear (parameter value 1) or quadratic (parameter value 2) decay function is used. A linear function is regularly chosen because of the conceptual ease. A quadratic function is often chosen because of the link with the Newtonian gravity law, which forms the basis for the potential accessibility measure and which works with a quadratic (interaction) function. As a consequence, the choice of resistance parameter and functional form (potential decay function or an isochrone of interest) depends to a large extent on the wishes of the decision-maker.

as a resistance component, although this is not a disadvantage of the measure itself: costs can (theoretically) be incorporated. Another possible disadvantage of the measure, according to Geurs and Van Wee (2004), is that the measure is not able to incorporate temporal constraints, such as the availability of opportunities at different times of the day and the time available for individuals to participate in certain activities. Whether this is a serious flaw depends largely on the purposes for which the measure is used. However, even if is possible to add time constraints, the question remains whether this will lead to more realistic model outcomes at regional or supra-regional levels. In the field of traffic simulation studies, for example, (simple) macroscopic simulation models, which operate at a more aggregate level of traffic streams, work satisfactory at higher levels. Micro simulation models (capturing more individual effects) are more applicable to lower levels. This indicates that it is not always necessary (or better) to incorporate individual specific effects at higher geographical scales. The final choice concerning which level and detail of modelling to apply in a study depends, however, on the purpose of the study, and thus on the requirements of the decision-maker. Finally, compared to contour measures, potential measures have one substantial disadvantage: the difficult interpretation and communicability. They are not easily interpreted and communicated as opportunities are divided by resistance: the outcomes form a combined effect of the number of (reachable) opportunities and the impedance to reach them.

In conclusion, potential measures meet the criteria involved in data requirements and the scale of modelling. They also have some theoretical advantages compared to contour measures. A disadvantage is that they are more difficult to interpret, which makes it harder to communicate their outcomes, for example, to policy-makers. Nevertheless, although the resistance component needs to be adjusted to include costs, these measures appear to have potential when it comes to modelling accessibility under pricing conditions.

The third and final location-based group of indicators distinguished by Geurs and Van Wee (2004) are the balancing factors of Wilson's double constrained spatial interaction model (Wilson, 1971). Balancing factors are derived from potential measures. Therefore, generally speaking the same advantages and disadvantages to apply to potential measures apply to balancing factors as well. In addition, a major advantage of balancing factors is that they explicitly handle competition effects. The measures ensure that the magnitude of flow originating at zone i and destined at zone j equals the number of activities in zone i and j. In addition, operationalisation seems to be an advantage. The measures can be computed using state-of-the-practice land-use and transport demand models. However, a major disadvantage is that balancing factors perform considerably worse when it comes interpreting and communicating the results compared to the contour and potential measures.

Person-based measures, another type of indicator, analyze accessibility at the individual level (see also section 2.4.2). These types of measures satisfy almost all of the theoretical criteria as a result of the disaggregate approach. The measures are useful for a social evaluation of land-use and/or transport changes as individual characteristics and constraints are taken into account. However, this approach also leads to problems with respect to the criteria that are considered important for modelling the accessibility effects due to pricing in this thesis. Detailed information on individual activity travel is required, which in most cases is very situation-specific, which makes applying the measures at an above-local level and transferring the outcomes to other situations/regions difficult. Because of the volume of data required and the complexity of the modelling process itself, the computational effort involved is also larger compared to location-based measures[21]. Research into the operationalisation of the concepts of space-time geography into indicators is ongoing, whereby using utility theory seems to be fruitful. However, the disadvantage of the (high) data requirements and the ongoing research for operational algorithms make space-time measures not directly (and easy) applicable for modelling accessibility effects due to road pricing.

The final category of accessibility measures that can be discerned are the measures based on utility-theory. Utility measures are often estimated on the basis of empirical data. A well-known measure based on utility-theory is the logsum measure (Ben-Akiva and Lerman, 1985; see Pieters, 2003, for an application). Utility-based measures are useful for economic evaluations because cost components are usually included. Another advantage is that the measures show diminishing returns: non-linear relationships between accessibility improvements and user-benefit changes. There are disadvantages as well. Due to the complex utility theory it is difficult to interpret and communicate outcomes.

Measures based on utility theory differ from location-based measures in that they do not measure 'actual' accessibility, but rather the valuation of accessibility. The great advantage of utility theory is that measures can be developed that satisfy most of the theoretical criteria. However, aiming at fulfilling all criteria makes measures complex. Currently, no such measure is known to exist. Attempts have been made, for example, to use utility-approaches to make space-time measures (Miller, 1999). Nevertheless, the use of utility theory for modelling accessibility does not necessarily have to mean that measures are complex and detailed. The concept of generalized transport cost, for example, converting all kinds of impedance components into cost terms, is also related to utility theory (see Bates *et al.,* 2001). Utility theory itself may thus offer useful ways to improve other types of measures, such as the earlier mentioned way of using utility approaches in space-time geography. Using a generalized transport cost function in location-based measures can be seen as combining utility theory with more geographical based accessibility approaches.

In conclusion, none of the currently available accessibility measure can be used directly to study the accessibility effects of (road) pricing. However, some measures seem more suitable than others, in some cases after they have been adapted to meet the relevant requirements. Space-time measures, first of all, seem to be the least suitable, especially due to their high data requirements. Secondly, utility-based measures are quite complex, although utility theory can be used to improve other measures. Thirdly, classical location-based measures, such as the contour and potential measure, seem to meet the criteria being used quite well. However, they require specific tailoring of the resistance component/function to be able to take the cost and benefit components of road pricing into account, and to allow for important characteristics (and or perceptions) of groups of people. A way to incorporate costs into classical accessibility measures, such as contour or potential measures, is to use a generalized transport cost approach. Thus, combining utility theory (i.e. a generalized cost component) with a more classical location-based measure seems to be a potentially fruitful way to model the accessibility effects as a result of or under pricing conditions. Although the suitability of certain indicators (in this case contour and potential measures seem to be suitable) was assessed, the question remains which further refinements have

21 This computational effort may, however, be less of a problem given the ever increasing computer capacities.

to be made to the resistance function and which processes have to be taken into account when modelling accessibility effects of (road) pricing with these 'suitable' measures. Section 2.5.3 will elaborate on this.

2.5.3 - Towards modelling accessibility effects as a result of road pricing

2.5.3.1 - Introduction

This section describes directions for modelling (realistic) accessibility effects due to (road) pricing, focusing specifically on 'well-suited' accessibility measures following from section 2.5.2 (contour and potential accessibility measures). Section 2.5.3.2 provides a theoretical overview of the characteristics that should (ideally) be regarded when tailoring the resistance function of accessibility measures. Subsequently, section 2.5.3.3 formulates considerations that have to be kept in mind in modelling accessibility effects due to road pricing. These two first sub-sections, 2.5.3.2 and 2.5.3.3, start from a more or less ideal situation. In reality, it is hard and maybe unnecessary to take all suggested refinements and processes into account in modelling geographical accessibility effects due to (road) pricing: the modelling process would become (too) complex. Therefore, section 2.5.3.4 proposes a 'simplified approach' to modelling realistic accessibility effects as a result of (road) pricing measures with a reasonable effort.

2.5.3.2 - Tailoring of the impedance component of accessibility measures

Geographical accessibility measures, such as the contour and potential measures, consist of a location and a resistance component. The location component indicates which or which type of activity location(s) is/are central within the analysis. Examples of activity locations are jobs, shops, amusement parks, etc. The second component indicates the trouble/difficulty involved in reaching a destination from a certain origin location. This can be expressed in various factors the most important of which are distance, time and costs. In modelling (realistic) accessibility effects due to road pricing, important cost (road pricing) as well as benefit (e.g. lower travel times) components of road pricing have to be taken on board.

The resistance component of accessibility measures like the contour and potential measures needs to be adapted to incorporate pricing effects. In many (practical) accessibility measure applications travel time is used as resistance. Travel time can be seen as an important impedance factor, also in case of road pricing, since travel time is affected by pricing measures. With respect to road pricing, travel time can be converted into a monetary component by multiplying it with a valuation of time ('value of time': see, for example, Hensher, 2001; Hensher and Greene, 2003). Other cost components, such as costs due to road pricing and various trip-related costs (e.g. fuel costs, maintenance costs of the vehicle) can then be included in a single generalized cost function.

Because of the importance of travel time as a resistance component, travel time valuations should be taken into account in a correct way. A specific point of attention translating travel time into financial terms is the possible presence of non-constant values of time. The amount of travel time saved (because of a road pricing measure) can influence the value of travel time saved (Gunn, 2001; Rietveld, 2003). If someone saves, for example, one minute of travel time, that single minute has little practical value. Therefore such a small timesaving may not be valued at all. On the other hand, if someone manages to save 20 minutes, one minute saving may take on a completely different value for that person, because now that one minute can be put to good use, thanks to the fact that it is part of a larger 'time saving interval'. Moreover, valuations between travel time gains and losses may differ. Travel time losses in this respect seem to outweigh gains, meaning that people are willing to spend more (money) to save a certain amount of 'loss time' than to save (the same amount of) 'gain time' (Gunn, 2001; Wardman, 2001). Gunn (2001) also points to a third aspect of the non-constant valuation of time: someone having a longer actual travel time may value travel time gains or losses differently than someone with a shorter travel time. Although the possible emergence of non-constant travel time valuations in time may have implications for the modelling of the accessibility effects as a result of road pricing, recognition of these non-constant valuations is also important in other circumstances that are not related to road pricing, for example the evaluation of time gains produced by a new railroad or motorway.

Applying non-constant travel time valuations alone may from a theoretical point of view still not lead to a realistic resistance function when road pricing effects have to be studied. Important aspects that may not be left out are the differences between groups of people and the way they value time. People with different socio-economic or demographic characteristics have different values of time. Higher income households, for example, have higher time valuations than people with lower incomes, which is why important (group) characteristics that influence the value of time have to be taken into account. However, the question is whether the sum of the total costs minus the benefits (also expressed in costs) leads to a good representation of how people actually 'feel' or perceive accessibility. With respect to road pricing all other kind of factors, which in most cases are probably hard to measure, can be important in influencing the way people feel or perceive resistance. These perceptions of resistance and thus accessibility may be influenced, for example, by different attitudes of people, such as (negative) attitudes towards road pricing as such or a reluctance to changing their behaviour due to road pricing, etc.. In principle the assessment of differences between perceived and more objective measured resistance is important in all kinds of accessibility studies, and in the case of road pricing determining these differences may even be more important because the resistance to road pricing in different countries is high (Runhaar, 2001). This resistance may influence people's perceptions (or maybe the other way around). Clearly there is no such thing as one 'general' perception: the perception of accessibility may vary based on important (measurable) socio-economic and demographic factors.

Closely related to valuations of travel time are valuations of travel time reliability. By implementing road pricing in a congestion-prone area, the reliability of travel time may increase. This can be seen as a benefit component of road pricing. People seem to value the reliability of travel time (see, for example, Bates *et al.*, 2001; Lam and Small, 2001; Noland and Polak, 2001), so taking reliability into account in the resistance part of accessibility measures would presumably make accessibility outcomes under pricing conditions more realistic. Additionally, these values should be differentiated according to important characteristics that influence the valuation of reliability.

In conclusion, to model the accessibility effects under or due to road pricing conditions, some refinements to the impedance component of accessibility measures such as contour and potential measures have to be made. Values of time can be used to monetarize the travel time impedance into financial terms. Road pricing costs can then easily be added to the resistance component leading to a single generalized transport cost function. Additionally, accessibility outcomes can be made more realistic by differentiating values of time on the basis of important socio-economic or demographic characteristics, to take account of the possible non-constancy of travel time valuations in time and to incorporate values of reliability into the resistance function. Furthermore, it is important to assess differences in people's perceptions of accessibility and more objectively computed accessibility. In the following section the attention will be shifted towards the recognition of the processes which have to be regarded in order to model realistic accessibility effects due to (road) pricing.

2.5.3.3 – Considerations in modelling accessibility effects due to road pricing

In this section we discuss important aspects in the process of computing the accessibility effects as a consequence of road pricing. First of all, it is important to recognize the possible behavioural changes of people due to road pricing. Road pricing measures may lead to changes in the traffic volumes at different time periods in the short-term. In the longer-term changes in locations may also occur. All these behavioural changes have an impact on accessibility. Secondly, possible effects of (the way) revenues from pricing policies are used, on accessibility have to be considered. This means that various processes need to be taken into account:

- Short-term (behavioural) changes due to road pricing measures;
- Long-term (behavioural) changes due to road pricing measures;
- Effects of revenue use on accessibility.

Short-term (behavioural) changes

As stated earlier, travel time gains are an important benefit component of road pricing. Changes in travel time occur as a result of changes in people's behaviour. Important short-term changes: changes in departure time, route (choice), mode of transport and/or frequency of travel.

These behavioural changes may influence the (perception of) accessibility. The changes may have an impact on congestion. When (some) people change their departure times, for example due to a time-dependent charge, this may lead to a more equal spread of traffic demand throughout the day. Subsequently, changes in itinerary, due to a location/road-dependent pricing measure, can lead to an improved network performance (on average across the network), because traffic demands are dispersed. Road pricing policies may also result in (partial) changes in the mode of transport or may affect the frequency with which certain trips are made. These behavioural changes on aggregate influence the accessibility of locations at a certain point in time. Although accessibility in essence is a location (and time) dependent concept, (groups of) people may make decisions to change their behaviour on the basis of how they 'perceive' accessibility. Their perception may be influenced by all kinds of aspects, such as their feelings and attitudes towards a pricing measure itself and towards its (expected) effects.

Behavioural changes in the short-term can make it necessary for accessibility measures to be made more dynamic. This is the case, for example, when some (groups of) people decide to change their departure times due to a time-dependent charge. When it is not possible to make accessibility measures more dynamic (or time-dependent), the existence and dimension of those changes at least have to be taken into account in describing the computed accessibility changes due to road pricing, to avoid reaching (partially) erroneous conclusions with regard to 'true' accessibility effects. Moreover, the simulation of accessibility effects ideally should not only focus on the car mode but should also take other modes into account, such that a more complete picture of the accessibility effects of road pricing (including the changes between modes) can be given. A good insight into the (size of the) behavioural changes can be derived from empirical research (see, for example, chapters 5, 6 and 7, which focus on these kinds of behavioural changes). A second method is to use a traffic simulation model. Such a model should only be considered if it deals correctly with short-term behavioural effects due to road pricing measures.

Long-term (behavioural) changes
In the longer-term, actors may decide to make changes in their activity locations. In the medium to long-term, households can, for example, choose to shop or recreate elsewhere, etc.. Also, firms may, for example, look for suppliers elsewhere. In the longer-term households can decide to adapt their residential and/or work location and firms may decide to change their settlement location. From a theoretical 'completeness' point of view the accessibility measure/construct should incorporate such location changes. However, the complexity (and non-transparency) of the modelling process would increase rapidly: changes in activity locations influence the location component of accessibility measures and these location changes cause network loads to change, leading in turn to changes in the resistance part of the measures[22]. To estimate such effects a land-use transport interaction model is needed. Whether or not such extra effort is profitable, depends on the purpose of the research.

Revenue use of (road) pricing policies
Road pricing policies lead to revenues. Governments can decide for what purposes they want to use those revenues (provided the measures are publicly funded) (see e.g. Small, 1992; Litman, 2005; Ubbels and Verhoef, 2005). Revenue use can be divided on the basis of whether they have a short-term or a longer-term impact. When revenues are used, for instance, to lower fuel or car taxes (or to a certain extent general taxation) that has an immediate effect on accessibility. On the other hand, when they are used to fund infrastructure, the benefits may not be felt in the immediate future. Those longer-term revenue effects are therefore harder to take into account in modelling accessibility, although it is important to be aware of the existence of the longer-term benefits.

2.5.3.4 - Discussion: practical applicability versus realism
To assess the suitability of different accessibility measures to model accessibility effects due to or under road pricing conditions we formulated several criteria in section 2.5.2. These criteria in fact are also relevant in deciding which refinements have to be incorporated into the impedance function of measures and additionally can be used for choosing the processes which (at least) have to be accounted for when accessibility effects of road pricing are actually modelled. Especially the trade-off between the realism of outcomes and the applicability of the modelling process is important. Taking into account more of the refinements and processes mentioned in the sections 2.5.3.2 and 2.5.3.3 enhances realism, although it also increases the complexity and thus reduces the applicability of the modelling process. A point for consideration is which refinements are crucial in modelling the accessibility effects as a result of road pricing and which are basically improvements for the modelling of accessibility in general. By assessing the modelling complexity and the extent to which outcomes are realistic, this section provides some

22 Furthermore, changes in location demand may lead to changes in house price, which in turn can affect location choices (see also chapter 6).

initial direction towards a practical way to model geographical accessibility effects due to (road) pricing measures. Additionally, chapter 4 provides some further and more detailed considerations and recommendations for modelling (realistic) accessibility effects on the basis of an examination of the sensitivity of accessibility outcomes for different 'configuration' characteristics.

When modelling the accessibility effects due to (road) pricing some choices have to be made regarding the tailoring of the resistance function. Including values of time in the resistance function is essential for modelling accessibility effects of road pricing. The level of differentiation in values of time[23] that should be applied relies on two points. Firstly, it depends on which factors (i.e. socio-economic, time-related or other characteristics) have an important effect on the way people value time. Secondly, it depends on the sensitivity of accessibility outcomes to the configuration of the generalized transport cost function (i.e. including the size of the values of time). If accessibility outcomes are relatively insensitive to varying values of time it may, for example, not be necessary to put much effort in differentiating the generalized transport cost function towards many value of time influencing characteristics: the outcomes will hardly be affected by the 'extra' differentiation. Chapter 4 focuses on studying this sensitivity and derives some implications with regard to the configuration of the resistance function.

In theory the accessibility effects due to pricing can be determined both for individual persons and for firms. However, from a practical point of view it may be harder to model the accessibility changes of firms than of individuals, due to the fact that the way firms value time is more difficult to measure, because in general firms are made up of a variety of individuals and decision makers[24].

As described in section 2.5.3.3, it may also be worthwhile to include a time reliability component in the impedance function of accessibility measures because actors seem to value travel time

23 This refers to the differentiation required with respect to (important) socio-economic/demographic characteristics and the non-constancy of travel time valuations.

24 In case of trying to derive firm-related values of time, decisions must be made regarding who of the employees within a firm (e.g. management personnel) can provide an exact and reliable quantitative insight into those appraisals. Even though employees in general may agree on the importance of travel time and travel costs, the actual quantifications may vary substantially. Ideally, several 'key' persons within a firm are asked to give appraisals. However, this is a costly and expensive procedure. A less costly approach is to estimate values of time for business-related trips by interviewing individual business travellers. However, it is rather unclear as to what an individual business traveller in such a situation actually represents (see also Wardman, 1998; Wardman, 2001). Although some individual employees may bear in mind the company policy in giving indications for time valuations, according to Wardman (1998) it is not inconceivable that the individual provides answers that essentially represent his own valuation rather than that of the company. In addition to this, there is the issue of whether respondents know and accurately take into account their company's travel policy when instructed to do so (Wardman, 1998). This makes it hard to determine the validity of their statements. Additionally, Fowkes (2001) mentions some other approaches to approximate firms' time valuations. One is by using gross wage rates plus non-wage labour costs (e.g. pension, insurance and other costs that vary worker hours) and another one by valuating what an employer can produce with an extra hour of labour (i.e. the marginal product). However, all these approaches are more difficult and/or outcomes are probably more uncertain compared to individual persons' time valuations.

reliability. Refining accessibility measures by incorporating values of reliability is not only important in modelling accessibility effects under road pricing conditions, but would be an improvement in measuring accessibility effects in general. Whether or not a reliability valuation should be incorporated and to what level of detail depends on the extent to which actors value reliability, and it also relies on the extent to which including value(s) of reliability in the generalized transport cost function affects the sensitivity of accessibility outcomes. In chapter 4 the sensitivity of accessibility outcomes to varying values of reliability is not tested. However, the sensitivity is tested for a variety of other cost characteristics, among other things the value of time. The sensitivity of outcomes to these other cost-related characteristics can also provide insight into the usefulness of incorporating (different) values of reliability.

As discussed in section 2.5.3.3, the realism of the accessibility outcomes will be enhanced when behavioural effects and revenue uses are taken into account. Short-term effects due to road pricing are important since these effects lead to travel time changes (and thus benefits). Anticipating the short-term behavioural changes that are described in chapter 5 (section 5.3), it would appear that a majority of current car trips (of car drivers) are not changed due to (road) pricing measures: in general more than 85 percent of the current car trips remains the same. The accessibility of the group of people who (almost) do not alter their trip behaviour is influenced by changes in the costs due to the pricing measure. This is a *first-order effect*. Additionally, because some people do change their behaviour, the traffic situation (e.g. travel times especially in areas with traffic congestion) is modified, in a way that also affects the accessibility of people who do not change their behaviour. This can be seen as a *second-order effect*. To model realistic location based accessibility effects for this group, these traffic impedance changes should be taken into account. Such changes can, for example, be determined by using a traffic assignment model (see also chapter 4 for an application). To derive realistic accessibility changes for the people who do change their behaviour, a distinction must be made in the type of behavioural change. In case people choose to adjust their departure times, their second-order accessibility changes should be computed between the location-based accessibility in the time period before and the period they would choose after the introduction of pricing. Correspondingly, when people choose another mode of transport, (group) accessibility changes should ideally be computed by determining differences in resistance between the different modes of transport being used, although formally the accessibility of a location itself (i.e. not the accessibility of people living at that location) may not change as a result of some people choosing a different mode of transportation. In the case of changes in trip frequency, actual accessibility changes are hard to determine: e.g. people no longer make a certain trip anymore. Such differences may then be best ascertained using a utility-based approach. If one does not want to make the (large) effort required to model 'realistic' accessibility changes for the group of people who do change their behaviour, and if additionally one wants to keep the modelling process transparent, an alternative approach may be to compute their accessibility changes without assuming they have changed their behaviour, but letting them benefit of the (fictitious) changes in travel resistance (e.g. travel time) they have helped to bring about. When one applies this (paradoxical) procedure, possible improvements in the accessibility of these people are underestimated, whereas any losses are overestimated. This happens since in 'reality' those actors change their behaviour when a pricing measure is introduced in order to reduce their (perceived) generalized costs. It may be worthwhile applying this simplification in practical studies that need to be carried out at a reasonable cost. Ultimately, this simplified approach measures realistic effects for a majority of the people involved (i.e. those who do not modify their behaviour). For the group who do change their behaviour 'worst case' scenarios are derived. It may be important to be aware that for the latter group 'worst case' effects are measured. Additionally, when reporting accessibility effects in a (practical) study it may also be valuable to provide details about the size and characteristics of this (minority) group. Moreover, it may be useful to calculate how much they 'lose' on aggregate by computing the aggregate economic welfare loss of these people (i.e. the change in consumer surplus) using the 'rule-of-half'. Assuming a linear decreasing marginal benefit function with increasing traffic volume, the loss in consumer surplus is equal to ½*(number of car trips changed)*(increase in generalized price) (see e.g. De Borger and Proost, 1997). This general price increase is equal to the difference between the charge level and the financial benefits (e.g. due to travel time reductions).

As described in section 2.5.3.3, long-term behavioural changes may influence accessibility in the long-term. Anticipating on results in chapter 6 and 7, a considerable majority of actors (households and firms) do not relocate. This may lead one to assume that the simplified approach mentioned above may remain useful even when longer-term accessibility effects are regarded. However, whether or not these long-term changes should be taken into account also depends largely on the goal of using the accessibility measure. In the sensitivity study in chapter 4 activity locations are assumed to be fixed.

As argued earlier, revenues from road pricing may influence individual accessibility in the short as well as in the long-run (see section 2.5.3.3). Some types of revenue rebates that directly influence the generalized transport cost function may be easily taken into account in modelling accessibility effects due to road pricing. An example of such a rebate is the abolition of fixed car taxation. Other types of reinvestment that influence the transport and land-use system in a specific region (e.g. creation of new infrastructure) may be harder to incorporate. In chapter 4 the sensitivity of accessibility outcomes is computed for adding a revenue rebate component to the generalized transport cost function, i.e. a lowering of fixed car taxations. One may also opt in favour of not including revenue rebates when computing accessibility effects. However, it then is important to keep in mind that the accessibility changes one has computed in effect are 'worst case'-scenarios[25], since generally speaking reinvestment of revenues will most likely result in an unchanged or improved accessibility compared to not incorporating the revenue rebates (e.g. because of reinvestments in the transport system).

An important consideration in accessibility simulation studies is the difference between computed accessibility and 'perceived' accessibility (see section 2.5.3.3). Refining the impedance component, through the application of values of time already leads to a not totally objective impedance function. Costs such as road pricing or fuel costs might be rather objective. Values of time on the other hand represent personal (not objective) valuations, which might differ per individual and lead to a subjective (perceived) accessibility. But, modelling accessibility in this way may still be different from the overall perceived accessibility of individuals. Differences between perceived and more objective accessibility are important to keep in mind in all kinds of accessibility studies. However, in case of road pricing, differences between perceived and objective accessibility may even be more important. Because resistance to road pricing is high in various countries (Runhaar,

25 This is at least the case if we assume that car drivers will not be worse off as a result of the way revenues are used.

2001), it is to be expected that the gap between perceived accessibility and objectively measured accessibility will be higher when looking at the effects of road pricing measures compared to other, more neutral, policy measures. Within this thesis we have made a first attempt to study the influence of such perceptions (see Appendix D and section 4.5).

In conclusion, in this section (i.e. 2.5.3) we have provided directions for tailoring the impedance function of classical accessibility measures and formulated important processes that have to be accounted for when actually modelling the accessibility effects due to pricing. Finally, we discussed some first directions for a practical way of modelling geographical accessibility effects due to (road) pricing measures. In chapter 4 some further implications for modelling (realistic) accessibility effects as a result of road pricing are derived on the basis of a sensitivity analysis study. In the following two sections we look at the location effects, and more specifically at the influence of transport-related characteristics on residential and work location choices of households on the one hand, and on the effect of transport on settlement location choices of firms on the other.

2.6 - The influence of transport on location decisions

2.6.1 - Introduction

In this section the influence of transport on location decisions of households and firms is described. Section 2.6.2 explains the role of transport in the micro-economic location theory. Section 2.6.3 provides more empirical evidence regarding the strength of the relationship between transport and residential and work location choices of households. Thereby, section 2.6.3.1 positions the 'transport-household location' literature within the overall field of studies regarding household location choices. Subsequently, section 2.6.3.2 distinguishes several stages that occur in household relocations. Furthermore, the actual empirical evidence regarding the strength of the relationship between transport and residential or work location choices of households is described in section 2.6.3.3. Section 2.6.4 describes empirical evidence regarding the influence of transport on firm relocations. Section 2.6.4.1 first provides an overview of different firm migration theories and recognises the existence of various stages of the relocation process of firms. Section 2.6.4.2 then focuses on empirical evidence regarding the influence of transport (characteristics) on firm (re)locations. Conclusions are presented in section 2.6.5.

2.6.2 - Micro-economic location theory

Micro-economic location theories, especially (further) developed in the 1960's, are often used as a basis for building theories regarding the relationship between residential and work locations. These theories are based on the neoclassical micro-economic theory of consumer and producer behaviour. Consumers as well as producers strive for profit maximization. Most of the micro-economic models look at the residential location choices of households given the work locations (Wingo, 1961; Muth, 1969; Alonso, 1964). However, some theories focus on firm locations as well, such as the business location theory, the classic theory formulated by Christaller, and the industrial location theory first formulated by Weber (see for an overview Giuliano, 1989). Central to (almost) all theories is the influence of transport costs. Transport costs are traded off against other factors such as land prices. The models make presumptions in order to make it possible to compute where consumers (households) and/or producers (firms) find their economic equilibrium, leading to the final location choices. Although presumptions may be somewhat different (or less detailed) in the various models, there is some level of agreement (see also O'Farrell and Markham, 1974; Verster, 1986; Van Wee, 1997):

- Households substitute travel costs for housing costs (land prices) and the rate of substitution is governed by each household's preference for high or low density living and/or high or low travel costs;
- Jobs are assumed to be centralized (located in the same centre/central business district);
- Travel costs are an increasing function of distance from the employment centre;
- Site rents (or price per unit of land) decline with distance from the central business district;
- The income elasticity of demand for space is positive, meaning that households try to raise land consumption (i.e. they prefer to have bigger housing lots).

Because transport costs are low near the central business district, where jobs are located, and higher away from the centre, households with a higher preference for land will be found relatively further away from the centre. In contrast households with a lower preference for land will locate more centrally. In this respect Alonso (1964) introduces the concept of bid price curves. These curves present the price people are willing to pay for land, which decreases with distance from the centre at a rate just sufficient to produce an income effect, which will balance the increased costs of commuting (O'Farrell and Markham, 1974).

Differences between models presented by authors such as Alonso (1964) or Muth (1969) are based on different choices in relaxing strict assumptions of the micro-economic location theory, leading to an increase in realism of the modelling process. Alonso (1964), for example, extends the model to three instead of two budget categories; next to land and transport costs a category other 'expenditures' is added. Subsequently, Alonso not only focuses on household locations, but on firm locations as well (Van Wee, 1994), where assumptions are tailored specifically to firms. All firms, for example, are identical and sell in competitive markets. Each firm generates a (normal) profit, can sell as much as it wants and faces the same set of production costs as other firms (see Tillema, 2005). The market place for goods and services is in the city centre, meaning that firms have to transport their products to this place. Like in household location assumptions, transport also plays a key role in the firm location model. Muth (1969), on the other hand, only takes households into account, although he adds an extra work location centre and relaxes the assumption of constant transport costs from all directions to the central business district (see Van Wee, 1994). Moreover, more dynamic processes, such as the influence of increased car possession on house (price) demand, are included. Thus, although differences exist, these trade-off models all start from the same basis, with transport costs being an important factor in location choices. For a more complete overview of these but also other location theories, see O'Farrell and Markham (1974), Verster (1986), Van Wee (1994), Bruinsma (1994).

Although classical micro-economic location theory forms a good starting point for explaining the location choices of households and firms, the applicability of the models in real world situations seem to be limited. Classical theories have too many simplifying assumptions, whereas reality is complex (see O'Farell and Markham, 1974; Verster, 1986; Van Wee, 1994). First of all, using a mono-centric city, with all jobs located in the city centre, does not correspond to reality. Furthermore, classical theories assume that perfect information is available to households (or firms) on the basis of which they can decide where to locate. In reality, however, perfect information is not available, and even if it were, it is doubtful whether people are able to/will take all the information into consideration: people may rather be regarded as satisficers instead of optimizers. Also, classical theory fails to take into account that people behave differently and are faced with different circumstances, for instance in terms of the mortgage they can afford, which will influence their location decision in no small measure. Also, classical theory assumes that people make their decisions in a kind of social vacuum, and that any obstacles with regard to their possible decision to relocate are not taken into account. Additionally, looking at the housing market the assumed perfect market equilibrium does not exist in reality. The market can, for example, be distorted due to monopolistic elements, leading to less than ideal competition effects and less freedom of choice. Also, the idea that people's decisions are above all influenced by where they work is not always reflected in the real world (see Van Wee, 1994).

However, the main (general) criticism is that the classical theories that emerged in the 1960's overemphasize the importance of transport costs in people's location decisions compared to other factors like household characteristics (for example, O'Farrell and Markham, 1975; Weisbrod *et al.*, 1980). These findings are based in particular on more empirical studies, which have become popular since several statistical techniques, such as discrete choice models, have become more practically applicable. The next section will, therefore, look more specifically at the influence of transport time/costs in location decisions based on empirical studies from the last approximately thirty years. It is, however, important to state also that in practice the distinction between the 'micro-economic' location theories and empirical evidence regarding the strength of the relationship between transport costs and location decisions is not always so clear-cut. Many of the micro-economic theoretical models are models that provide insight into the 'size' of effects only by estimation on the basis of empirical data.

2.6.3 - Transport and household locations: empirical evidence

2.6.3.1 - Position of transport within overall household location literature

A large body of literature is available on residential mobility originating from different fields of research, such as geography, sociology, economy and psychology (Dieleman, 2001). Some authors have attempted to categorize the many research directions (see, for example, Clark, 1982; Dieleman, 2001). These categorizations are partly time-dependent, because shifts in research focus and new study fields may emerge over time. Clark (1982) provides an extensive overview of research on migration and characterizes the literature until the beginning of the 1980's. He classifies the literature into three geographical (migration) scales, namely international, interregional and intra-urban migration, and in particular works out the research directions for the latter two spatial levels. Within these geographical layers available studies can be assigned on the basis of whether they use a 'macro' or 'micro' approach. Many early studies on residential relocation are based on macro-approaches analysing migration processes at an aggregate level, without distinguishing between different agents (i.e. individuals, households). These macro-analyses are not an ideal level of research because existing aggregate-level models do not possess a high degree of predictive power and furthermore the understanding of the nature of individual responses to environmental conditions (i.e. the micro-approach) will provide a sounder basis for evaluating a number of decisions related to planning of growth, development and reorganization of urban areas (Brown and Moore, 1970). Thus, the individual approach, also known as the behavioural approach, was largely stimulated by the lack of specificity that could be derived from aggregate analyses of migration flows. The 'micro-based' literature identifies who is likely to move and what their choice of housing is likely to be (Dieleman, 2001). In this respect Rossi (1955) can be considered one of the pioneers in the field of migration research from a micro-perspective, whereby he particularly focuses on the influence of life cycle influences on residential relocation.

Although, as pointed out by Clark, the literature before the 1980's makes a strong distinction between interregional and intraregional migration (i.e. intra and partly inter-urban), this difference has lost a lot of meaning since (Van Wee, 1994). Van Wee explains this by the spatial expansion of the labour and housing markets, caused partly by the improved infrastructure networks. Therefore, the physical boundary between geographical scales becomes less important. Nevertheless, the classical distinction between the two spatial scales implies that making a distinction between geographical/spatial scales is useful (Van Wee, 1994).

A more recent review article in the field of residential mobility was written by Dieleman (2001). Rather than reviewing all (new) publications he singles out the ones that seem to break 'new ground'. The review is organized according to a diagram (see figure 2.2). At the core of this figure are the residential relocation choices of households. These are choices at a micro-level. The micro-level residential location choices are embedded in circumstances in at least three geographical layers, which influence the relocation choices. These geographical layers are the particular housing market a household lives in (metropolitan level), the national economic and demographic circumstances as these develop over time (national level) and the difference in housing prices, wealth and tenure which shape the residential mobility process (international level). Research at the macro-level is not considered in figure 2.2. This may indicate that micro-level research has become the major field of research within residential migration. Some reasons for this gradual shift from macro to the micro-level were already stated before (i.e. low predictive power of macro-level models and a sounder basis for evaluating migration decisions). An additional reason for the interest that micro-level research has gained, however, is the progress made in the development of discrete choice models (see, for example, Louvière *et al.*, 2000; Train, 2003) since the second half of the 1970's. With respect to the residential migration research at the micro-level, three elements of the mobility process (according to Dieleman) have been given systematic attention in recent years. Firstly, the observation that the decision-making frequently involves more than one individual has led to the household being the relevant research object. Secondly, systematic attention is given to the observation that many households cannot find or afford the dwelling of their first choice and have to find an acceptable alternative. In the third place the relationship between changing jobs and changing houses takes an important place in literature. The job-related and residential locations can be regarded as an interdependent construct; job relocation may lead to changes in commuter accessibility (expressed in generalized transport costs) and may form a trigger to change the residence location and vice versa. This research direction seems to have won ground since the review article of Clark (1982), although he already pointed to the relationship (summarized as 'accessibility') between urban residences and workplaces too[26]. In spite of the importance of the commuting trip for the job and residential location, literature does not provide an unambiguous answer to the question whether the work or

26 '…while the workplace may not be the critical dimension in the reason for relocation, it serves as an important constraint on that relocation behaviour within a city. To that extent, it is an important element of the contextual impact of urban structure on relocation behaviour'[Clark, 1982].

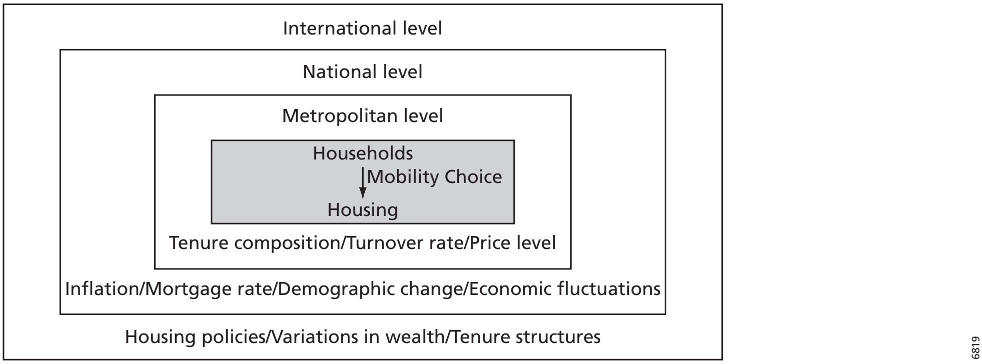

Figure 2.2: residential relocation and its embeddedness in three geographical scales (source: Dieleman, 2001)

the residential location is the dominant one. Although there are different views on this subject, as yet no a priori choice of dominance of one location above another one seems to be preferable in research (see Verster 1986; Van Wee, 1994). In conclusion, a large body of literature is available on residential mobility, originating from different fields of research and therefore also with different perspectives on the migration process. An important direction in household-migration research looks at the relationship (accessibility) between job-related and residential locations. Existing studies can be divided on the basis of whether they are theoretical modelling-based (see section 2.6.3.2) or partly empirical (see section 2.6.3.3).

2.6.3.2 – Phases in the relocation process

Relocation decisions consist of several stages. Vickerman (1984) distinguishes three. Firstly, decision-makers have to decide whether to enter into a search process for improvement. Then, in a second phase they have to identify what, if anything should be changed. Finally, they need to establish a decision rule for the precise change to be made. There are other authors that divide the process into two stages (Brown and Moore, 1970). The first phase is the 'decision to seek a new residence', whereas the second phase involves 'the relocation decision'. Finally, Verster (1986) also mentions a two-staged relocation process: on the one hand the decision to leave the current location (mover, push model), and on the other hand the decision to locate somewhere, after conducting a successful search (distribution or pull model).

Focusing on a two-stage relocation process (i.e. the choice to relocate and the final decision where to locate) the first stage is caused by a disequilibrium phenomenon (Weinberg, 1979) and can be termed the 'awakening'. This implies that a household realises that it either currently or somewhere in the foreseeable future can improve its housing and/or job conditions (including the access to destinations such as the job itself) by moving elsewhere (Devisch, 2005). According to Weinberg (1979) no relocation would take place unless there were outside shocks to the system. Various shocks/triggers/stressors can lead to an awakening (see, for example, Weinberg, 1979; Clark, 1982; Clark and Dieleman, 1996; Dieleman, 2001), which may be related to changes in the (lifestyle of the) household (household composition, income or changes in preferences) but also to external factors, such as changes in the environment (e.g. socio-economic status of the neighbourhood). Moreover, various triggers exist which can lead to a change in job location, such as moving to another residential location, but also changes in job satisfaction and the (lifestyle of the) household (for example getting children leading to higher time constraints) can be seen as triggers, as can (the offering of) new job opportunities or changes in accessibility. According to Brown and Moore (1970) changing locations is not the only way the stress may be reduced or maintained within acceptable limits. They distinguish three possible actions: firstly adjusting needs, secondly restructuring the environment relative to the household so that it better satisfies household's needs, either of which would result in a decision not to migrate and thirdly relocating the household, either in part or as a whole. Finally, once the decision to relocate has been made the household will engage in a search process in order to find a dwelling or job that better matches its preferences on a set of criteria, including the characteristics of the house/job and the environment.

2.6.3.3 – Influence of transport on location decisions of households

Although interaction between land-use and transport is a commonly accepted concept, questions remain regarding the strength of the relationship between transport and land-use. The impact of transport on location choices and land-use (i.e. the whole spatial constellation of activity locations) has attracted much less attention of empirical researchers than the influence of land-use on transport (see section 2.3). However, in studying the effects of road pricing policies on (re)location choices of households and firms, insight into the influence of transport on location choices[27] (and land-use) is particularly important. In section 2.6.2 we indicated that the role transport is assumed to play in relocation decisions of households in classical economic theories may be overestimated. Since the 1960's, several empirical studies have investigated the importance of transport (costs) on relocation decisions. This body of empirical research can be grouped into studies that focus on the overall location (and in the end land-use) impacts of transportation investments (e.g. building new roads or railway infrastructure) on the one hand, and studies that look at the importance of (commute) trip impedances (i.e. level of service of infrastructure) on the residential or work location choice of households on the other hand. This section particularly focuses on the latter group of studies because it is more relevant with respect to road pricing. However, first the empirical evidence of the influence of new infrastructure will shortly be described.

Building new infrastructure (i.e. first literature class) can influence the economic processes at different geographical levels. Nevertheless, the influence of (new) infrastructure on relocations of households is not very clear. The location effects of new road infrastructure partly seem to depend on the quality and density of the available infrastructure (see Giuliano, 1989; Geurs and Ritsema van Eck, 2001). In places where a dense road network is available relocation effects of building a new road may particularly have local effects (for example, it may attract (new) households). On a larger scale (i.e. regional or higher) redistributive effects may occur (i.e. redistribution of spatial activities between regions). Also, the influence of public transport infrastructure on location choices and on land-use is not entirely clear, as can be derived from literature reviews given by Giuliano (1989), Wegener and Fürst (1999), Badoe and Miller (2000). The general impact of new public transport infrastructure on household relocations seems to be relatively small, but as with

27 If locations change, this does not have to mean that land-use changes. Land-use can be seen as the entire spatial constellation of different human activity locations such as living, working, shopping, education, leisure etc. People can change locations without affecting the overall land-use picture.

road infrastructure this will most likely depend on the density and quality of the already available infrastructure network.

The empirical studies (implicitly or explicitly) concerned with studying the importance of (commute) trip impedances on household location choices can mainly be divided into two methodological classes: studies based on stated preference/choice data and on revealed preference data. The stated preference experiments in these cases especially aim at determining the importance of transport related characteristics versus more specific work and house (location) related variables in the location decisions of households (see, for example, Rouwendal and Meijer, 2001; Molin and Timmermans, 2002; Timmermans *et al.*, 1996; Weisbrod *et al.*, 1980). Rouwendal and Meijer (2001) used stated preference/choice data concerning Dutch workers to assess the relative importance of housing, employment and commuting-related variables in location preferences of households. They did this by estimating multinomial as well as mixed logit models. In general the authors find that households dislike commuting time. However, preferences for some housing attributes such as the size of the town/city or the type of house are strong enough to make substantially longer commuting acceptable to most workers. Correspondingly, Weisbrod *et al.* (1980) conducted a stated choice research to analyze moving decisions and residential choices of individual households. Their results suggest that transport costs indeed do influence residential location preferences and that significant trade-offs are made between transport costs and other factors such as housing costs and aspects of the living environment. However, the role of transport again is relatively small compared to socio-economic and demographic factors. Thus, their results are comparable to Rouwendal and Meier (2001). Molin and Timmermans (2002) review the relative importance of accessibility on residential choice on the basis of six different stated preference/stated choice studies. The results of these six studies suggest that regardless of the study area and the model specification accessibility considerations are significantly less important than housing attributes and attributes related to the neighbourhood. It seems that as long as people have the opportunity to afford flexible means of transport, the impact of accessibility on their residential location choice behaviour is limited. However, a marked difference between this study by Molin and Timmermans and those described before lies in the definition of accessibility. Whereas Rouwendal and Meier (2001) and Weisbrod *et al.* (1980) focus on the commute resistance, the review of Molin and Timmermans (2002) looks at accessibility from a broader perspective. Next to commuting-related accessibility, accessibility to several other types of locations such as shops, facilities, public transport stops, etc., are taken into account. The decision made by Molin and Timmermans (2002) to take a broader approach of accessibility rather than merely honing in on the influence of commute related accessibility also seems to have made it more difficult to interpret the differences among the studies they have examined. The six studies they review vary considerably in the way they deal with accessibility, on the one hand because they appear to use different factors to explain accessibility, and on the other hand because they do not always make it clear what it is when they talk about accessibility. Nevertheless, in general the stated preference researches point to location and house/work related characteristics being possibly more important in location decisions than transport factors.

Giuliano (1989) gives a review of revealed preference researches, and reaches a conclusion that is similar to the one discussed above, namely that, although the concept of trade-offs between transport costs and location decisions is still valid, the observed pattern is affected by other (random) factors. The second conclusion is that transport costs are no longer a key factor in people's decisions where to locate. Taken as a whole, the empirical record according to Giuliano suggests that the second conclusion is more accurate. She argues that transport costs are much less important than location theory predicts. This is primarily the result of decentralization and a well-developed transport system that has reduced differences in accessibility between locations and increased the importance of local characteristics, which is in line with the results from the stated preference researches. Additionally, Giuliano believes that the importance of local characteristics has increased in importance because of scale economies in development (for example larger space demand by larger firms), agglomeration economics and the regulatory influence of local governments. Further evidence of the limited role of transport resistance in (re)location decisions is given by O'Farrell and Markham (1975). Based on research among Dublin commuters, they find that a majority of car-owning commuters have never considered the cost of travelling to work by car and have never traded-off site cost against travel cost in the residential location decision. Thus, they conclude that the friction of the 'space effect' is exerting little or no influence upon residential decisions on the periphery of the urban area.

Another body of revealed preference research focuses specifically on studying changes in commuting distances due to changes in the residential and/or work location. Clark *et al.* (2003) consider the commuting responses of one and two-worker households. The methodology is partly empirical, in that it examines commuting distances before and after a residential and/or work location on the basis of a longitudinal dataset. In addition, Clark *et al.* developed a modelling application for the probability of decreasing the commute distance. Empirical and model findings indicate that both one- and two-worker households with greater separation between work and residence tend to reduce distance and time. However, there does not seem to be a continuous relationship between distance and relocation. The data used provides confirmation of the importance of a critical isochrone[28] beyond which the likelihood of decreasing the distance to work grows rapidly (see also Clark and Burt, 1980; Verster, 1986; Van Ommeren *et al.*, 1997). The authors conclude that commuting distance does matter and households are actually aware of the trade-off between distance to work and the residential location. The links between residential and job location may even increase due to the growing number of two-worker families as households in such cases struggle with changing separation of work and residence. Moreover, a series of papers use the theory of search, which motivates the modelling of commuting distances, as a theoretical background and compare empirical results obtained from longitudinal revealed preference data with this theory (see, for example, Rouwendal and Rietveld, 1994; Van Ommeren *et al.*, 1997; Van Ommeren *et al.*, 1999). In contrast to for example Clark *et al.* (2003), Rouwendal and Rietveld (1994) find that people who change job will often commute over a longer distance after the change occurred. Changes in people's housing situation however are neutral in their effect on the average commuting distances. On the basis of their research Van Ommeren *et al.* (1999) conclude that job and residential mobility both increase with commuting costs. This result is a consequence of the underlying assumption that commuting is costly. Correspondingly, Zax and Kain (1991) also found a higher relocation probability for longer commuting distances.

In conclusion, empirical studies seem to suggest that transport resistance is less important in location decisions than assumed in the classical micro economic location theories. Stated

28 With respect to the possible existence of critical or constant travel time budgets, see also Van Wee *et al.* (2002).

preference researches indicate that the characteristics of house and work (in addition to people's personal characteristics) are possibly more influential in location decisions. However, several revealed preference studies still find a relationship between commuting distance and location choices. Thus, although transport resistance may not be as important as micro-economic location theories would have us believe, that does not mean that transport does not play a role in relocations. The exact influence on location choices is still somewhat unclear. In general the studies into the influence of transport on household location choices also do not make a clear distinction between the different phases in the relocation process (see section 2.6.3.2). Most studies implicitly seem to focus on the influence of transport in the search process of a location, whereas a more complete picture would be gained by looking at the influence of (changes) in transport resistance on both the relocation probability and on the search process. Finally, almost all studies focus on the influence of transport on location decisions in relationship to the commuting trip. In reality however, other activity locations, such as shopping and or leisure locations may also have an impact on the location choices.

2.6.4 - Transport and firm locations: empirical insights

2.6.4.1 - Theories concerning firm relocation and phases within the relocation process

In general three groups of location theories may be used to study business location issues and the forces that drive the selection of business locations (see Pen, 2001; Brouwer *et al.*, 2004): the neo-classical, the institutional and the behavioural location theories. The neo-classical theory is based on the classical micro-economic theories we discussed in section 2.6.2. The institutional location theory starts from the assumption that economic activity is socially and institutionally situated: it is shaped by society's cultural institutions and value systems rather than by firm behaviour (Brouwer *et al.*, 2004). The focus lies on spatial organisation and the actors, and the location problem disappears to the background. The behavioural location theory, on the other hand, does focus on relocation and interprets firms as decision-making agents that have limited information, are subject to bounded rationality[29], and settle for sub-optimal outcomes rather than maximum profits. Within this theory the decision process with regard to location and migration decisions of firms is especially important. In the simplest case, the same stages in relocation processes can be distinguished as described in section 2.6.3.2 (i.e. relocation choice and the actual location choice). However, much more detailed decision-making patterns have been developed within the behavioural theory field (see also Van Dijk and Pellenbarg, 2000; Pen, 2001). Van Dijk and Pellenbarg, for example, describe a process developed by Townroe with five successive stages: stimulus, problem definition, search, formulation and comparison of alternatives, choice and action. The choice stage is further divided into eight subsequent steps (see Van Dijk and Pellenbarg, 2000). However, Van Dijk and Pellenbarg (2000) indicate that even more complicated models of the location decision-making process exist. These schemes and models are rarely applied in empirical research, and therefore less complex decision-making frameworks are preferred[30].

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29 People are only partly rational, and are in fact emotional/irrational in their actions. Bounded rationality suggests that economic agents employ the use of heuristics to make decisions rather than a strict rigid rule of optimization (Simon, 1955).

30 For example, three stages: orientation phase, selection phase and negotiation phase (see the overview given by Van Dijk and Pellenbarg, 2000).

2.6.4.2 – Influence of transport on location decisions by firms

Three main categories of factors influencing firm locations can be found in literature: internal factors (e.g. size, e.g. employment, profits), external factors (e.g. market size, government policy) and location factors (e.g. location site, accessibility) (see Brouwer *et al.*, 2004). On the basis of micro level data (i.e. at the firm level) from both a (longitudinal) revealed and stated preference origin, Van Dijk and Pellenbarg (2000) conclude that internal factors seem to be most important in the relocation decisions of firms. Especially 'going through the various stages in the life cycle' is an important explanatory variable within this category. In contrast, the characteristics of the present location (including accessibility) seem to play only a limited role in the explanation of the propensity to migrate. Thirdly, external factors also seem to be of little importance.

In their conclusion that transport does not have the influence micro-economic theory ascribes to it, Van Dijk and Pellenbarg (2000) are generally supported by other studies (see, for example, Pellenbarg, 1999; Pen, 2001; McQuiad *et al.*, 2004). Possible reasons for this relatively limited influence of transport on firm relocation decisions are (see McQuiad *et al.*, 2004):

- In developed countries transport provision is ubiquitous. Therefore, transport is regarded as a necessary location condition that does not differ substantially between certain places in Western countries;
- Transport costs are only a small part of a firm's overall operational costs;
- Transaction costs for relocating may in general be too high to enable firms to react 'freely' to transport or accessibility changes/differences.

Nevertheless, a major problem with various studies that examine or review the effect of transport on firm relocation is their general lack of common ground. Pellenbarg (1999), for example, reviewed the influence of transport on firm migration derived from several empirical studies. Although he found that, in themselves, accessibility, transport and infrastructure remain important location aspects, there still is a substantial confusion as to their exact influence, because (Pellenbarg, 2005):

- The content of the lists of settlement factors differs strongly within different studies;
- The operationalization of the transport and infrastructure factors varies substantially between different studies;
- Different researchers place a different value on certain factors, which has an impact on the results.

This lack of unity can have a large impact on the results. An important difference between studies that fit into the second category mentioned above, for example, is the implicit difference between transport provision (new infrastructure) (see also Bruinsma, 1994) and accessibility (the level of service of provided by the transport infrastructure) (Pellenbarg, 1999). The influence of transport infrastructure on relocation is considered quite small, because of the 'level playing field' with respect to infrastructure provision. Nevertheless, accessibility would appear to be important. On the basis of a literature review McQuiad *et al.* (2004) conclude that current and expected levels of services provided by transport infrastructure (e.g. the quality, reliability, time etcetera) are a crucial component in the actual location decisions.

Moreover, the extent of the influence of transport on relocation may depend on other aspects, such as the stage in the decision process or the geographical scale. In each decision stage another set of variables can be the most important factor. Van Dijk and Pellenbarg (2000) and McQuiad *et al.* (2004) find that transport is especially important in business relocation when the decision to move has already been made. The geographical scale can be of influence regarding the importance of transport for relocation choices; according to McQuiad *et al.* (2004) the evidence suggests that transport becomes an increasingly important factor for businesses as the geographical scale is reduced from supranational to local.

In conclusion, the influence of transport on relocations is likely to be less than it is argued in micro-economic theories (section 2.6.2). However, due to a lack of uniformity in the operationalization of 'transport' in different studies, the impact of transport-related variables on relocation decisions is still not exactly known. Several studies seem to indicate that the influence new transport infrastructure has on relocation is limited. By contrast, the influence of transport service indicators, such as travel time and reliability of travel time seem to be more important. However, according to McQuiad *et al.* (2004) at the moment not enough empirical evidence is available regarding the influence of transport service indicators. Finally, accessibility from a geographical perspective, such as employee/customer access, is found to be an important indicator for firm relocation. Problem is, however, that accessibility is defined in different ways in different studies. All this means that a lot is unknown about the influence of transport on firm relocation.

2.6.5 - Conclusions

The influence of transport (cost) on household and firm relocations remains on first sight rather unclear. The classical economic location-theories are based on the trade-off between transport costs and land. Within these theoretical studies transport plays an essential role in relocation. However, empirical research, but also studies that present outcomes by using theoretical models that are estimated on the basis of empirical data, indicate that transport has less of an influence on relocation than is supposed by the classical micro-economic theories themselves. Yet, a problem is that the empirical studies in general do not apply a uniform definition of transport. Some studies focus more on the influence of new transport infrastructure, whereas others take level of service factors (such as travel time) into account. Because of the difference in operationalization, various studies find different effects regarding the influence of transport on relocation, ranging from a very small influence to a substantial or even large impact. However, the general tendency in literature is that transport costs are of a (substantially) lower importance than the theoretical models (without using empirical data) suggest. Although the influence of transport on location decisions of households and firms does not seem to be large, the influence of road pricing on relocation decisions may be larger than 'normal' marginal changes in transport costs, because road pricing costs in most cases are more directly linked to the travelling/driving itself. Thus, people or firms may feel the cost of their actions more directly. Furthermore, road pricing measures can be targeted at achieving certain types of changes (e.g. a time differentiated charge to reduce the traffic congestion in peak periods). Yet, how do such road pricing measures influence transport costs and as a consequence people's travel and location behaviour? Section 2.7 gives a first insight into the evidence derived from literature regarding the link between road pricing and relocations of households and firms. As will be shown, however, relatively little research on the influence of pricing policies on (re)location choices has been undertaken. Finally, in this section we argued that the relocation process of households and firms consists of different stages. A distinction in at least two phases, the relocation decision and the choice of the actual location, is found to be important because transport factors may have a different influence in different stages of the relocation process.

2.7 - Road pricing and relocation of households and firms: insights from the literature

The spatial/location effects of road pricing policies have not been extensively studied in literature. The studies that do exist can roughly be subdivided into more qualitative theoretical or conceptual studies on the one hand, and modelling studies on the other. Empirical studies are lacking, as we already pointed out in chapter 1, section 1.3. The aim of the current section is not to report all available literature on spatial effects of road pricing policies, but to categorize the literature, to give examples within each category and to discuss the literature in general. Because of the relatively limited amount of literature and the importance of literature on this topic for this thesis, the separate studies within this section are described quite extensively. This is somewhat in contrast to the description of literature regarding the influence of transport on (re)location (section 2.6). Section 2.7.1 reviews some qualitative theoretical or conceptual studies. Section 2.7.2 focuses on modelling studies. Finally, the conclusions are presented in section 2.7.3.

2.7.1 - Qualitative theoretical and conceptual based evidence of relocation effects

Within the category of theoretical/conceptual studies a distinction can be made between studies that are based on earlier research on pricing or transport related topics and those that form a more conceptual insight into the possible or expected effects. Examples of the first type of studies are MuConsult (2000) and Blok *et al.* (1989). MuConsult (2000) carried out an extensive study concerning the spatial effects of pricing policies based on theoretical reasoning as well as on the results of studies in related fields (e.g. the effects of parking fees). The aim was to obtain insight into the spatial effects of pricing policies with regard to persons/households and firms. The pricing measures being studied are: a kilometre charge, a cordon charge and a parking charge. An important subdivision made in this research is the distinction between short-term and long-term effects. Short-term effects are transport network effects consisting of possible changes in travel pattern, such as changes of mode or changes in departure time. Long-term effects are defined as changes in the location choice of households and firms as a consequence of road pricing. An important conclusion is that a considerable part of employees can transfer costs onto their employers. For this group the incentive to change location behaviour is low. On the basis of earlier research (i.e. primarily transport cost elasticities) MuConsult estimates that approximately five percent of all employees will search for another job due to a kilometre charge. This may increase to seven percent in case of strong price increases. The residential relocation change to the contrary is expected to be lower in the case of a kilometre charge (three to four percent of the employees)[31]. In contrast to the kilometre charge, Muconsult reports a higher expected percentage of residential location change (3-5 percent) than job relocation (1-2 percent) when a more toll-

31 However, these results are not based on an empirical research into the effects of a (uniform) kilometre charge, but are primarily derived on the basis of a mix of elasticities and modelling exercise results derived from different researches. Therefore, no clear insight is provided into the influence of the price level on the relocation chances.

based charge (i.e. pay at certain points[32]) would be introduced[33]. No reason for this difference due to the type of road pricing measure is given. Additionally, the settlement relocation probability of firms is expected to be negligible, mainly because transport costs (also related to employee compensations) only form a small part of the operational costs of firms (see also section 2.6.4.2). However, more footloose firms are assumed to have a higher relocation chance. The effects of Muconsult's study in general confirmed the study of Blok *et al.* (1989), who carried out a largely qualitative exploration of the possible spatial effects of a cordon charge variant.

Banister (2002b) and Vickerman (2005) look more intensively at the relocation question from a conceptual point of view. Banister (2002b) focuses on the possible impacts of a road pricing scheme such as the cordon charge in London. This study was carried out before the actual implementation of the congestion charge in London. As there were no data available Banister only presents a series of researchable propositions based on the assumption that the charging level in London is likely to have a measurable effect. He distinguishes short and longer-term impacts. Focusing on the longer-term effects (i.e. relocations) Banister concludes that we know little about the actual effects. Congestion charging may increase the attractiveness of the central city through reduced travel times or may decrease attractiveness through increases travel costs. On the other hand, the net effect may well be no change at all. Over time, the causality links become increasingly blurred, as other factors (e.g. the property market and building construction cycles) also intervene. According to Banister, it is also hard to distinguish congestion-charging effects from existing processes such as decentralization. Vickerman (2005) looks at the expected spatial effects of London's congestion charge and at the simulated effects for the non-implemented cordon charge in Edinburgh. In London, it would appear that especially some/a few retailers have moved away from the charged city. However, the London charge was only implemented in 2003, which means that it is too early to predict, let alone measure the spatial effects thoroughly. Vickerman focuses not only at describing the London and Edinburg results but aims more specifically at studying the suitability of (simulation) models in their current form to be used as a forecasting tool for assessing spatial effects. Some of the arguments/comments given by Vickerman in this respect are addressed in section 2.7.2, where, among other things, the shortcomings of current modelling approaches in the case of road pricing are described.

2.7.2 - Modelling based insights into relocation effects

Modelling-based studies form the second research category. Three different types of models can be distinguished: analytical economic general equilibrium models, large-scale urban simulation models and combinations of these two models. The analytical economic equilibrium studies (see, for example, Arnott, 1998; Anas and Xu, 1999; Mun *et al.*, 2005) find their basis in the micro-economic theory described in section 2.6.2. They all aim at assessing the effects of a cordon charge. Differences between the studies particularly originate in trying to relieve (some of) the

32 For the toll charge the study uses the Dutch Rekeningrijden-scheme (proposal by Ms. Netelenbos, the Minister for Transport, Public Works and Water Management in the cabinet Kok-II 1998-2002). This pricing scheme consisted of charging cars for passing toll points located mainly around the four largest cities in the Netherlands. Rekeningrijden was intended to reduce congestion problems, but was never actually implemented.

33 MuConsult (2000) reports that the 'rekeningrijden' scheme in itself implies a 5 to 7 guilder (i.e. 2.2 to 3.2 euro) charge per passage of a toll portal (in the morning peak).

strict assumptions made in the classical micro-economic models. Arnott (1998) applies a mono-centric city approach with all jobs located in the central business district (CBD). He estimates effects of a cordon charge using a 'standard model' and a 'bottleneck model'. The innovation of the bottleneck compared to the standard model is that the bottleneck model is dynamic, meaning that individuals can adjust their departure time from home (to work). Additionally, in both types of models, open and closed city models were estimated. In the case of the closed model the total population within the study area does not change. Application of the bottleneck and of the standard model lead to different results. In the standard model the implementation of a cordon charge leads to a spatial concentration of economic activity. Travel will become more expensive when a congestion toll is introduced, which would discourage travel and encourage building at higher density. In case of the bottleneck model the social cost of traffic is reduced without any reduction in the amount of travel by relocating travel over the rush hour. When revenues are not redistributed, this optimal time-varying toll has no effect on the urban spatial structure and on land rents. Both types of models, however, can be seen as unrealistic in some respects (i.e. with respect to the effect of toll on the reduction in congestion). Arnott argues that the actual effects are likely to lay somewhere between the results provided on the basis of the two methods.

Anas and Xu (1999) also proceed from a cordon charge but apply a dispersed general equilibrium model, which does not assume that all available jobs are concentrated in one central location. The authors assume that jobs and residences are locationally unconstrained and that their spatial distributions are interdependent through labour and shopping markets. They conclude that in case of a cordon charge, two spatial effects work against each other. In dispersed cities, congestion tolls would drive up central wages and rents and would induce centrally located producers to want to move closer to their workers and their customers, paying lower rents and realizing productivity gains from land to labour substitution. On the other hand tolls would also induce residents to want to locate more centrally in order to economize on commuting and shopping travel. In the developed equilibrium model, the centralizing effect of tolls on residences takes precedence over the decentralizing effect of tolls on firms, causing the dispersed city to have more centralized job and population densities. A third type of approach, finally, has been suggested by Mun *et al.* (2005), who relax the assumption of mono-centricity, arguing that trips can occur between any pair of locations in a city, which is qualitatively different from that of a mono-centric city in which all trips are destined to a central business district. Two types of pricing are assessed: a first-best optimum charge and an optimal cordon pricing measure. The first-best pricing, not being realistic in practice, serves as a reference point for evaluating the performance of cordon pricing as a second-best policy. Cordon pricing is defined as the combination of the cordon location and the toll level that maximizes the social surplus in a city. The authors find that cordon pricing performs better as trip destinations become more concentrated around the centre. This suggests that cordon pricing is effective in cities where the urban structure is close to mono-centric. While people can adjust their choice of trip destinations to avoid crossing a cordon in a non mono-centric city, such a change would not be feasible in a mono-centric city where all trips are destined to the centre.

Next to the analytical economic general equilibrium models, large-scale urban simulation models are sometimes used to model spatial effects of road pricing policies (see, for example, Still *et al.*, 1999). An advantage of this type of models is that they can easily be applied to simulations on larger scales (e.g. detailed urban level) compared to micro-economic equilibrium models. A disadvantage, however, is that most of these models have to be calibrated to areas where they are being used, leading to a low generality: model results are difficult to transfer. Moreover, large-scale simulation models are often complex, which makes the modelling process less transparent. Still *et al.* (1999) examine and compare the validity and plausibility of the model results with regard to the implementation of two measures, a light rail system and a cordon charge system, in the city of Edinburgh (UK). Two types of models were used: land-use change indicators on the basis of accessibility and a more comprehensive land-use transport interaction modelling approach. Although the results from the different models are not always completely in line, the cordon charge seems to have a centralizing effect on the population and a somewhat decentralizing effect on employment within Edinburgh.

Eliasson and Mattsson (2001) have developed a 'stylised city model' that, among other things, can be used to simulate short and longer-term effects of road pricing measures. Their model is a cross between analytical urban economic equilibrium models and large-scale operational models. The strength of the economic models is first and foremost the theoretical rigour and generality, but there is a limit to how complex the models can be made. The large-scale models, on the other hand, are applicable to larger areas but lack transferability due to the needed calibration on a particular study area. The authors combine the strengths of both types of models: a quantitative simulation study with the theoretical strength of economic models. The simulation area is a schematic star-shaped city with a radial network connecting homogeneous zones. Four rings of nodes surround a centre node, where each ring contains eight nodes. There are four groups of actors: households, employers, shops and service establishments. The city is closed, meaning that the number of actors in each group is a given. Furthermore, three transport modes are available: car, public transport and slow mode. The authors use the simulation approach to study the location and transport effects of two forms of road pricing: a congestion charge and a cordon charge. The study concludes that based on congestion pricing, road pricing makes the city in general less dispersed. However, it is not primarily the city centre that grows denser but rather the innermost rings of the suburbs. The outer suburbs lose households, workplaces, shops and service establishments. Additionally, the price level of the road pricing measure may affect the location pattern too and the effects in that case will no longer be so obvious. When looking at a toll ring/cordon charge, location effects depend strongly on where the toll ring is located. If the area enclosed is large, locations outside the toll ring become less attractive (centralizing effect). Conversely, a small toll ring will cause households, workplaces, shops and service establishments to locate outside the ring. Mattsson and Sjölin (2002), finally, extend the model and analysis of Eliasson and Mattsson (2001) to the effects of a ring road connecting the innermost suburbs.

2.7.3 - Conclusions

Summing up the various types of models used may provide useful insights into location effects of pricing measures. But, the models also suffer from some serious shortcomings. To begin with, all models focus specifically on an urban level whereas serious congestion problems (also) occur on the motorways connecting the places/cities (see also Banister, 2002). Secondly, the models do not make a distinction between different phases in relocation processes: the actual choice to relocate and the process of searching for another location (see also sections 2.6.3.2 and 2.6.4.1). Households within the models relocate specifically on the basis of the accessibility to jobs (and sometimes also the accessibility to shops or service locations, such as in the case of Eliasson and Mattsson, 2001); firms relocate to the most efficient position with regard to the residential location of employees. This can be seen as modelling the second stage of the relocation process (the search of the location). The influence of road pricing on the relocation probability itself, however, is not taken into account. Especially the economic analytical equilibrium models may overestimate the influence of travel cost on relocation, because they are based on the classical micro-economic models (see section 2.6.2). Subsequently, land-use transport interaction models as well as the economic analytical models are both quite static, not taking into account, for example, changes in the housing market. Additionally, analytical models are only applicable at lower scale networks and not at larger urban levels (Vickerman, 2005). Furthermore, especially simulation models often try to model location changes by taking into account many relationships, in an attempt to make the simulation outcomes more realistic. However, the question is whether this is the right approach, since incorporating new relationships in the model, often implies making various corresponding assumptions. Therefore, more complex or detailed models are not automatically preferable when looking for realism. Besides, more complex structures have the disadvantage of making the model less transparent and less communicable, for example, to policy-makers. According to Vickerman (2005) another important shortcoming of current models in modelling effects due to road pricing is that these models are based on the assumption of marginal changes in the access (or transport cost) values, while in reality actors like households and firms seem to value road pricing-related costs in a different way than they do 'normal' transport cost. A final shortcoming of the modelling studies, but in fact not a disadvantage of the modelling process itself, is that most modelling studies focus specifically on cordon charging measures.

As described in this section, literature on spatial effects of road pricing policies can be roughly subdivided into more qualitative theoretical studies and modelling studies. However, empirical evidence on effects of different road pricing policies on (re)locations of households and firms is lacking. This makes it difficult to determine whether or not road pricing, causing generalized transport cost changes, will lead to relatively stronger spatial effects than can be expected from 'normal' (marginal) travel cost changes (see also section 2.6.5). Empirical evidence in general can be derived in two ways. Firstly, by studying the spatial effects of pricing measures introduced at several locations in the world. Secondly, by studying the spatial effects in advance, by carrying out stated preference researches. Currently, the influence of the congestion charge in London on (especially) firm locations within the charged area is studied. It is hard to assess the longer-term location effects because the London charge was introduced in 2003 and relocation effects in most cases take more time to emerge. Moreover, a problem with studying the effects in such a specific case is that transferability of results is low; first of all, because of the specificity of the type of charge, and secondly, because of the characteristics related to a particular city or country. Stated preference studies would suffer less from these problems; the relocation effects under influence of different pricing measures can be assessed without actually implementing a measure. In addition, stated preference studies offer an opportunity to study influencing factors for relocation choices due to pricing measures, leading, for example, to insight into which kind of households or firms are more or less likely to relocate due to different types of pricing measures. A detailed insight into this is currently lacking. But, stated preference types of methods have shortcomings as well (see also Ortúzar and Willumsen, 2001). A very important one is the extent to which respondents are actually able to state how a road pricing measure would influence their location choices, for example because of the difficulty to imagine a certain measure and to actually 'feel' the cost linked to the measure. Nevertheless, stated preference research may substantially improve our insight into and understanding of relocation as a result of road pricing measures. Additionally, these insights may even be used to enhance existing forecasting type of (simulation) models.

2.8 - Conceptual model

In section 2.3 the concept of land-use transport interaction was explained and following from the presented feedback cycle first links between transport pricing, accessibility and location choices were presented. Subsequently, section 2.4 treated the concept of accessibility in more detail. Section 2.5 evaluated the suitability of different accessibility measures for modelling accessibility effects as a result of road pricing and addressed ways to tailor the resistance component. In addition, processes that have to be regarded in modelling accessibility changes due to pricing were assessed. The second part of the chapter elaborated more on the influence of transport costs (including road pricing) on location choices of households and firms (i.e. sections 2.6 and 2.7).

Now that geographical accessibility, location choices and the links with road pricing have (sometimes implicitly) been stated, this section combines all aspects into one conceptual model. This model can partly be seen as a further tailoring of the land-use transport feedback cycle presented in section 2.3 to a specific (road) pricing case. The conceptual model (figure 2.3) aims, first of all, at providing insight into the links between accessibility, trip behaviour and location choices and the way transport pricing influences the system. Secondly, the conceptual model shows additional light on the purpose of this thesis. Additionally, the conceptual model aims at providing a guideline for studying geographical accessibility and location effects due to or under pricing conditions within this thesis.

The conceptual model distinguishes three types of relationships (see legend figure 2.3). Boldly printed arrows represent important direct relationships between the boxes. The lines consisting of dots as well as small line segments indicate feedback loops. Dashed relationships finally show the effect of the 'black box' of contextual (or other influencing) effects. The model is particularly aimed at showing micro-level relationships, meaning relationships/effects on the individual or household level. Within the model, accessibility takes a central place. Accessibility (and accessibility measures in particular) consists of an opportunity and an impedance component. The opportunity part represents, for example, the activity locations. The resistance to get from one to another activity location is the impedance. Road pricing is a cost component and influences the generalized impedance. The resistance consists of factors such as travel time and/or travel distance or costs. This impedance or resistance is also influenced by other influencing factors (e.g. income).

On the basis of the perceived (changes in) accessibility, individuals/households or firms may feel the intention to change their trip pattern. Households can decide to change route, mode of transportation, departure time, frequency, and they may even decide to start working (more) from home for trips with different purposes. Firms can also choose to make such changes with respect to business trips and trips for the transportation of their goods. Whether certain changes take place is also dependent on the type of road pricing measure (via accessibility) and on other influencing factors and perceptions (for example the possibilities to change). Changes in a person's or firm's trip pattern may mitigate the micro-level burden or costs of the road pricing measure and thus influence the perceived accessibility of households and/or firms.

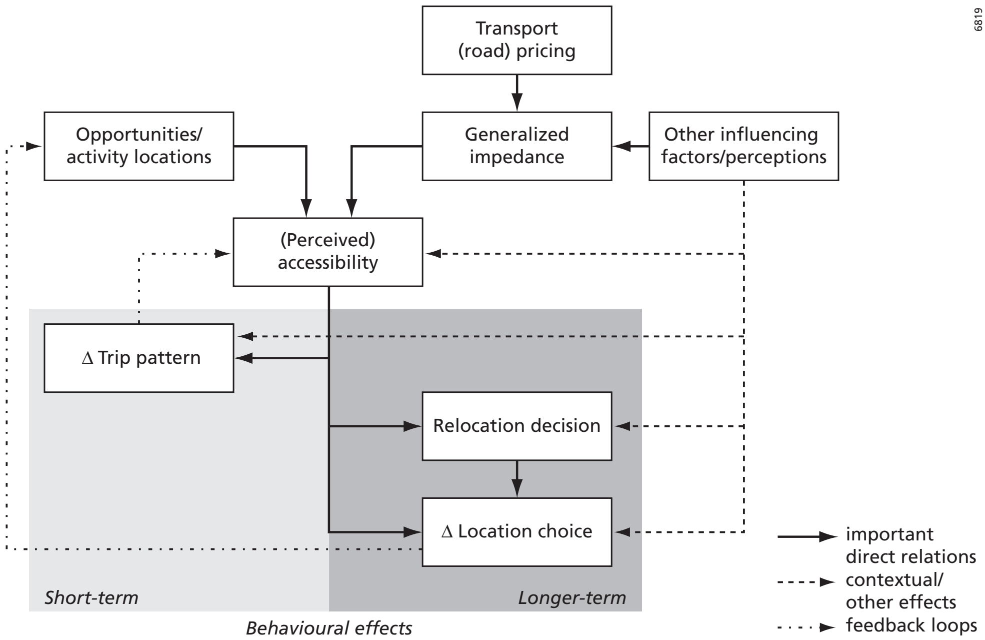


Figure 2.3: conceptual model showing micro-level linkages between transport pricing, accessibility and location choices

From a longer-term perspective[34], households may decide to make changes in 'easy adaptable' activity locations, for instance shopping, service or leisure locations. In the long-term households can decide to change their work and/or residential location. In the same way firms can choose to relocate. When a decision to relocate has been made, households and firms have to search for another location. If road pricing and accessibility play a role in the decision to relocate, it will also affect the residential location choice. However, if a household or firm chooses to relocate for another reason (represented by the box 'other influencing factors/perceptions' in figure 2.3), road pricing may still influence the choice of the activity locations[35, 36]. Road pricing not only affects relocation and the location choices following relocation. Road pricing may also influence the initial location choice of households or individuals entering the residential or labour market[37]

34 In the 'medium to long' term road pricing may also affect car ownership and the number of public transport season ticket holders.

35 Examples of household activity locations are: residential and/or work location but also, for example, shopping, service and leisure locations. Examples of firm activity locations are: their own settlement location and those of their customers and/or suppliers.

36 The process of trip pattern change in fact could also be divided into two stages (i.e. choice to make a change and the actual change). This distinction has however not been made in figure 2.3, because the focus in the figure is put especially on accessibility and relocations.

37 Individuals can for example enter the residential market in an area because they are going to live on their own (e.g. young adults) or enter the market from another region or country. Individuals can also enter the labour market when they leave school (graduated or not).

or the settlement locations of (new) firms[38]. (Changes in) the location choices of one actor in turn influence the actor's perceived accessibility via the changed opportunity/activity locations. The altered accessibility leads to a re-evaluation of accessibility and as a consequence trip pattern alterations.

The conceptual model has a generic character and does not specify which trip purposes and which type of locations are considered. Examples of trip purposes are: business, commute, shopping and leisure/recreational. Within this thesis, the behavioural effects of households are studied with regard to four trip motives (see motivation in chapter 3, section 3.4.4 and 3.4.5): commute, visiting, shopping and other. It must be remarked that the changes involved in the various purposes may vary in intensity. For example, changes in the trip pattern for shopping trips may influence the accessibility and location decisions to a lesser extent than changes in commuting trips. Looking further at the type of locations studied, this thesis focuses especially on residential and work locations of households and settlement locations of firms (see section 1.4.2). Moreover, it has to be emphasized that, whereas figure 2.3 shows conceptual links between the (perceived) accessibility of actors and the behavioural effects, these links between accessibility (chapter 4) and behavioural effects (chapters 5 to 7) are not studied specifically within the thesis. However, accessibility related aspects such as transport costs are taken into account as explanatory variables for studying behavioural effects.

Although macro-effects are not an explicit element of the conceptual model, they will be considered in this study. First of all, an important macro-effect is the influence of trip pattern changes on accessibility. Trip pattern changes aggregated over individuals can lead to travel time and reliability changes and thus influence personal accessibility. These effects are considered within the accessibility sensitivity study (see section 3.4.1, 3.5.1 and chapter 4). Subsequently, macro-effects are also considered in case of travel and location changes by aggregating results over individual households. A macro-level result is, for example, the percentage of households that consider relocation due to pricing (see chapter 6).

Some other (more) complex (second-order) macro-effects, which influence the micro level, are not explicitly studied within this thesis. Macro-effects occurring due to location changes represent a first example. Location changes can lead to a spatial change in location demands. This means that some locations may become more preferable than others. These demand changes can lead to altering housing/land prices. Changing prices in turn affect the location and relocation decisions. Additionally, on an aggregate level the individual location changes can lead to changes in the efficiency of trip patterns and thereby may influence the congestion level (i.e. in congested areas) and thus accessibility.

Revenue reinvestments are also not included in figure 2.3. Revenues may influence the entire system in figure 2.3. The type of road pricing measure influences the height of the revenues directly (through price level and type of measure). Additionally, (changes in the) trip and location patterns affect the total amount of revenues raised within a certain period. Revenues in turn, dependent on the type of reinvestment, may change the perceived accessibility. This may possibly

38 For example the settlement location of a firm that enters the market, because of a firm coming into existence or because it comes from other regions or abroad or due to firms starting up a new (sub) settlement.

affect behaviour. Aggregate effects of revenues[39] are not considered because of the wide range of possible revenue uses, which depend primarily on policy decisions. Moreover, aggregate effects of revenues are hard to study because they can vary in time and space (see section 2.5.3.3).

Finally, the complex interplay between firms and households is not explicitly studied within this thesis. Higher household transport costs due to pricing measures may lead to changing cost compensations offered by employers. These changes alter the operational costs of firms[40] and may influence firm behaviour. On the other hand a (higher) cost compensation derived by the households in turn will quite likely influence the households' behaviour under influence of a certain pricing measure. However, this is also dependent on the type of compensation received[41].

2.9 - Conclusions

This chapter focused on road pricing viewed from a geographical perspective. The geographical perspective was operationalized into two research themes: geographical accessibility and relocation. First geographical accessibility was defined and linked to road pricing in the first part of the chapter. More specifically, this first part aimed at studying to what extent current geographical accessibility measures can be applied to modelling accessibility effects as a result of road pricing, and furthermore to ascertain which aspects and processes have to be taken into account for modelling realistic accessibility effects due to road pricing. Subsequently, the second part of the chapter described the outcomes of a literature review concerning the influence of transport costs on the relocation of households and firms.

Geographical accessibility is a well-known concept often used in evaluating the transport-related effects of certain policy measures. Accessibility, therefore, could also be used as an indicator for getting more insight into the effects of a road pricing measure. Several categories of accessibility measures can be distinguished: infrastructure-based, location-based, person-based and utility-based measures. Not all these measures are equally applicable in every situation and as a consequence not all measures may be well-suited to determining geographical accessibility effects due to (road) pricing measures. In this chapter several criteria were formulated on the basis of which the suitability of accessibility measures in general and the suitability for modelling accessibility effects under pricing conditions can be assessed. General criteria are the theoretical basis of the measure (e.g. a measure ideally should take the land-use, the transportation, the temporal and the individual component into account), the operationalisation, the interpretability and communicability of measures, and the usability of measures in social and economic evaluations. However, applying the full set of criteria would imply a level of complexity and detail that can probably never be achieved in practice. Furthermore, important criteria, more specifically tailored to the situation of road pricing, were stated: realism of outcomes, ability to model on a

39 However, different types of revenue use are taken into account as explanatory variables in studying (some of) the behavioural effects of individuals.

40 These extra (transport related) costs are however expected to be small in proportion to the total operational costs of firms (see also Muconsult, 2000).

41 A relocation subsidy derived from the employer for example may trigger an employee to relocate due to road pricing, whereas a travel cost compensation will decrease the behavioural change propensity.

regional scale, low data requirements, method must be easy transferable to different regions and finally the accessibility outcomes must be easy interpretable and policy relevant. On the basis of all these criteria, the suitability of the different accessibility measures to be used in computing accessibility under pricing conditions was assessed.

Compared to other accessibility measures, classical location-based measures, such as the contour and potential measure, seem to satisfy the used criteria quite well. However, the resistance function of accessibility measures (in general) needs to be tailored in order to be able to take the cost and benefit components of road pricing into account. A way to incorporate costs into contour and potential measures is to use a generalized transport cost approach. Travel time can be converted into costs by multiplication with a value of time. Other cost components such as toll costs can then be added to the generalized transport cost function. The result is a single (generalized) cost resistance function. However, not everyone may be influenced by a pricing measure in the same way. To model realistic accessibility changes due to road pricing it is necessary to allow for important personal characteristics (and perceptions). This differentiation can, for example, be achieved by differentiating the used values of time in a cost resistance function towards influencing socio-economic and demographic characteristics.

Beside 'personalizing' the generalized transport cost function itself, certain processes have to be regarded in computing (realistic) accessibility effects due to (road) pricing. Important processes that influence accessibility are short-term trip changes (e.g. route, departure time changes etcetera). In addition, long-term location changes may affect accessibility as well via changing opportunity locations. Nevertheless, although these different 'processes' influence accessibility, it is practically almost impossible to include them all. Accessibility indicators would become too complex. Therefore, in simulating the accessibility effects due to road pricing, choices have to be made. Within this chapter a practical method was proposed with which realistic accessibility effects can be computed for a majority of car drivers. This method assumes that most households will not change behaviour due to pricing measures. This assumption is based on empirical findings reported primarily in chapter 5. Realistic accessibility effects can be computed for this 'no change' group by incorporating (next to pricing costs) travel time benefits that occur due to the smaller group of people that do change behaviour. Applying this same method for people who actually do change behaviour (i.e. incorporating travel costs and assuming 'fictitious' time gains that are actually caused by themselves) will result in a modelled underestimation of actual accessibility gains and an overestimation of losses for these people. This is discussed more thoroughly in section 2.5.3.4. In essence, the 'simplification' emerging from this procedure is that no effort needs to be put into modelling difficult accessibility changes for the group of people who do change their behaviour due to pricing: one then does not have to take account of time period, mode and frequency changes in computing accessibility changes for them. The accompanying motivation is that the mistake due to the simplification is acceptable because realistic effects are still computed for the large group of people that do not change behaviour. Whether this simplification is acceptable for actors (e.g. decision-makers, researchers) depends on their own goals and choices. The aggregate loss of people who change behaviour can still be estimated quite easily by computing the aggregate economic welfare loss of these people (i.e. the change in consumer surplus) using the 'rule-of-half'.

Finally further improvements in modelling realistic accessibility effects can be attained by considering revenue reinvestments. Some types of revenue rebates that directly influence the generalized transport cost function (e.g. lowering/abolishment of fixed car taxation) may be easily taken into account in modelling accessibility effects due to road pricing. Other types of reinvestment (e.g. building infrastructure) are harder to incorporate because, for example, they do not have a direct impact on accessibility or are more localized. It is up to the decision maker whether or not a certain type of revenue use is included in reality and in modelling accessibility effects.

Leaving the topic of modelling geographical accessibility and focusing on literature concerned with household and firm relocations, the exact influence of transport on location choices remains relatively unclear. Classical economic location theories form the basis of studying the relationship between land-use and transport. The models are based on trade-offs between transport costs and land. Within these modelling studies transport plays an essential role in relocation. However, empirical research on the influence of transport indicates that transport has a less strong influence on relocation. Nevertheless, a problem with the empirical studies in general is that they do not use a uniform definition for transport. Some studies focus more on the influence of new transport infrastructure, whereas others take 'level of service' factors (such as travel time) into account. Because of the difference in operationalization, various studies present different effects with regard to the influence of transport on relocation, ranging from a very small influence to a substantial or even large impact. Thus, the influence of transport on location decisions of households and firms is not totally clear. However, the influence of road pricing on relocation decisions may be larger than the impact of 'normal' marginal changes in transport costs, since road pricing costs in most cases are more directly linked to travelling/driving itself: actors may feel the cost of their actions more directly. In this chapter it was also argued that the relocation process of households and firm consists of different stages. A distinction in at least two phases, the relocation decision and the choice of the actual location, is found to be important. Transport cost may influence both phases of the relocation decision. Transport cost may, first of all, trigger relocation (i.e. the choice to relocate). When a relocation decision has been made either due to road pricing or due to another reason, transport costs may (still) influence the search process and the final decision where to locate/settle.

Next to the influence of 'general' transport characteristics on household and firm relocation, this chapter reviewed the relatively limited literature regarding the spatial/location effects of road pricing policies. The literature can be categorized into studies that examine spatial effects from a theoretical or conceptual basis and studies that use modelling approaches. However, as yet there is hardly any empirical evidence regarding effects of road pricing measures on relocation, partly due to the complexity of spatial effects, which take a longer time to emerge and to study. In addition, virtually all pricing schemes have been introduced fairly recently (for example the congestion charge in London), which means that the spatial effects have not yet taken place. Nevertheless, there are also no empirical studies based on stated preference researches. Because of a lack of empirical research it is difficult to determine whether or not (road) pricing, which will affect the generalized transport cost, will lead to relatively stronger or other spatial effects than can be expected from 'normal' (marginal) travel cost changes. This thesis partly aims to provide greater insight into spatial effects based on empirical (stated preference) research. The results from this empirical research are reported in chapters 5 to 7. Before moving on to the actual 'result' chapters, chapter 3 completes the 'theoretical framework' of this thesis (i.e. chapter 1 to 3), by describing the research methods and applied research design we used. More specifically, the chapter links the research questions presented in chapter 1, with research methods and the type of data used. Finally, we indicate which analysis techniques are used to answer the research questions in the remaining part of this book.

3 - Research methods and design

3.1 - Introduction

After chapter 1, the introductory chapter in which, among other things, research questions were formulated and chapter 2, in which we addressed the theoretical backgrounds, chapter 3 is concerned with research methods and research design. Central to this methodological chapter is the question how the research questions formulated in chapter 1 are answered within this thesis. First of all, we discuss the choices regarding the research methods required to answer the research questions. Secondly, the research methods frame the type of data that has to be used or collected. Finally, based on the type of data, techniques have to be selected that can be used to analyze the data and ultimately provide answers to the research questions (see figure 3.1).

The outline of this chapter is as follows. Section 3.2 provides an overview of the research questions presented in chapter 1. Section 3.3 describes the research methods that are used and links the different research questions to the corresponding research methods. Section 3.4 deals with the characteristics of the data we collected. Section 3.5 is devoted to explaining the analytical techniques that are applied within the thesis; this specific section limits itself to the explanation of techniques that are in themselves conventional, but which may not be considered common knowledge among all readers. Section 3.6, finally, presents an overview of the research design and methods used in the form of a table (Table 3.10). This table can be seen as a concretization of figure 3.1.

3.2 - Research questions

In all, four research questions have been formulated in chapter 1. Here, we only provide an overview of the questions. This overview is given because of the practical reason of avoiding the reader to constantly having to switch between chapters 1 and 3. The research questions are:

1. To what extent are current geographical accessibility measures applicable for modelling accessibility effects due to road pricing and which aspects and processes have to be taken into account for modelling realistic accessibility effects due to road pricing?
2. To what extent are geographical accessibility measure outcomes under road pricing conditions sensitive to varying cost (i.e. type of price measure, price level, specification of generalized transport cost function) and non-cost related aspects (i.e. accessibility measure, resistance parameter and network detail), and what implications for modelling geographical accessibility effects due to road pricing can be derived from these analyses?

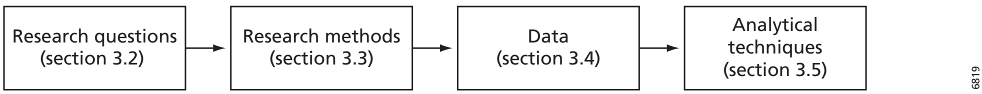


Figure 3.1: research process and chapter outline

3. To what extent do (road) pricing policies influence short-term trip/travel patterns and (re)location, especially work and residential location, choices of households?
4. To what extent does (road) pricing influence the perceived accessibility and short and long-term behaviour of firms?

The next section focuses on research methods that can be used to answer the various research questions.

3.3 - Research methods

This section analyses the pros and cons of different research methods, specifically with respect to the research in this thesis. Section 3.3.1 describes differences in the applicability of qualitative and quantitative methods. As we will argue, a quantitative approach is more useful in our research, which is why other sub-sections focus on describing the characteristics, including the advantages and disadvantages, of quantitative research approaches. Section 3.3.2 and 3.3.3 describe and explain revealed and stated preference research respectively. Subsequently, section 3.3.4 focuses on simulation studies. Finally, in section 3.3.5 research methods are selected that are applied in this thesis.

3.3.1 - Qualitative and quantitative research

Relevant literature distinguishes a range of different research methods that can be used to answer research questions (see, for example, Swanborn, 1987; Cozby, 1993; Frankfort-Nachmias and Nachmias, 1997; Verschuren and Doorewaard, 2001). Although these methods are often categorized somewhat differently, the general tendency is the same. In selecting suitable research methods, different but not necessarily mutual exclusive aspects can be weighed-out against each other. A first important consideration is whether any data need to be collected at all. If suitable data are available or if (empirical) data are not needed to answer a question, there is no need to gather further data (in the field). Research question 1, for example, was already answered in chapter 2. In retrospective, the method used to answer this question can be seen as a (sort of) office (desk) research[42] on the basis of reviewing literature, without explicitly using empirical data (see Swanborn, 1987; Verschuren and Doorewaard, 2001). A second, more methodological aspect regarding the choice of suitable research methods is whether a study is aimed at giving in-depth insight, for example into the behaviour of a specific actor, or whether the objective is to analyze the behaviour of larger groups in general. In the former case interviews are often conducted among (some of the) key actors, whereas in the latter case questionnaire studies are usually applied. Related to this is the question if the insight to be gained has to be of a more qualitative or quantitative nature. Qualitative analyses can often be conducted on the basis of in-depth interviews, giving insights in underlying processes and choices of individuals. Questionnaire studies, in which generally speaking a larger group of people is involved, are suitable for quantitative analysis.

This thesis aims at providing insight into the effectiveness of pricing policies (and at how to model effects), thereby focusing particularly on geographical effects (research questions 2 to 4).

42 Swanborn (1987) distinguishes the following four types of desk study: (i) analysis of public statistical material, (ii) literature research, (iii) secondary analysis on data collected by others, (iv) content analysis of mass communication texts.

The objective is to examine the behaviour for a 'large' group of actors (firms and households or individuals) to gain insight into aggregate results (i.e. the order of magnitude). This makes a quantitative approach more suitable than a qualitative one. *Questionnaires* provide a way to achieve quantitative insight into the effects of (road) pricing measures. There primarily are two types of questionnaire studies: revealed and stated preference studies. Section 3.3.2 explains the concept of revealed preference research, including the advantages and disadvantages. Section 3.3.3 does the same for stated preference studies.

3.3.2 - Revealed preference research

Revealed preference (RP) studies observe what actors (e.g. firm, households) actually do (or did), meaning that actual behaviour is studied. According to Ortúzar and Willumsen (2001), RP data have some limitations in terms of understanding travel behaviour, i.e.:

- Observing actual choices may not provide sufficient variability to construct valid models for evaluation and forecasting;
- The observed behaviour may be dominated by a few factors, making it very difficult to detect the relative importance of other factors;
- Difficulties emerge in collecting responses for policies that are entirely new.

This last point is particularly important when one is trying to gain insight into the behavioural effects as a result of a pricing measure. Because pricing measures have thus far been only implemented on a limited scale (throughout the world), relatively little is known about how actors behave due to or under a specific pricing scheme. Furthermore, the location effects as a consequence of pricing often emerge in the long-run and may not at all occur at the same point in time. Due to the fact that large pricing projects, such as the congestion-charging scheme in London, have been implemented quite recently[43], it is difficult or even impossible to gain a good insight into the location or relocation effects of such schemes on the basis of revealed preference data. 'Good' insight, especially into the long-term effects of a pricing measure, could be gained by undertaking a longitudinal real-life controlled experiment (see also Ortúzar and Willumsen, 2001). One can then observe actual changes in the location pattern over time. However, controlling the experiment is difficult because location changes may occur for other reasons as well. Additionally, these controlled experiments have other disadvantages, partially related to the costs of data collection. The costs involved in collecting data can be high when an actual pilot has to be carried out specifically for the experiment. However, a controlled experiment could, of course, link up with a pricing measure that is already (or is to be) implemented, making the costs involved in running a pilot less of a problem. Moreover, collecting data may be expensive because data have to be gathered by studying behaviour at different points in time, which is typical of longitudinal data. An additional disadvantage is the long time needed to study the location effects of pricing policies (i.e. because of the collection of data over time). Yet, even when sufficient budgets and time are available, the transferability of the results may still be low, first of all due to the specificity of a region in which a controlled experiment is being conducted, and secondly due to the fact that only one (or maybe a few) different pricing measures will actually be tested. Conducting controlled experiments at various geographical locations and for different (road)

43 The London congestion charge was implemented in 2003.

pricing measures[44] would make data collection costs even higher. Therefore, we can conclude that (at least currently) revealed preference type of researches are not (particularly) suitable for studying (especially longer-term) behavioural effects as a result of (road) pricing policies.

3.3.3 - Stated preference research

Stated preference (SP) researches can overcome some of the shortcomings of revealed preference studies. SP-techniques base estimates on an analysis of responses to hypothetical choices (Ortúzar and Willumsen, 2001). The advantage is that, by using hypothetical (experimental) situations, behavioural effects due to different types of pricing measures can be assessed. Moreover, long-term effects can be studied more easily because questions regarding (re)location intentions/choices can be asked directly to the respondents. Nevertheless, stated preference types of methods have shortcomings too. A very basic problem is to what extent what people say they would do reflects what they actually would if a situation arose (e.g. the introduction of a pricing measure) (Ortúzar and Willumsen, 2001). This is a disadvantage compared to revealed preference methods in which indeed the actual behaviour is observed. There may be a difference between the actual behaviour and behaviour observed within a stated preference context because respondents may find it hard to imagine a certain measure and to actually 'feel' the cost linked to the measure. Also, they may feel a need to provide 'socially desirable' answers or attempt to 'please' the researcher (although this also can play a role in revealed preference questionnaires). Finally, the difference may be due to positive or negative feelings towards the introduction of a certain measure, such as road pricing. Such feelings might also result in respondents answering strategically in an attempt to influence the results (and indirectly possibly the decision-makers). Nonetheless, Ortúzar and Willumsen (2001) state that, due to improvements in SP data-collection methods since the 1980s, very good agreement with reality has been reported from models using SP data. Therefore, stated preference based questionnaires seem useful for studying the behavioural effects as a result of new, planned or rarely implemented policy measures, such as road pricing. For a more elaborate overview of pros and cons of both methods, see Kroes (1988) and Louvière *et al.* (2000).

Different types of stated preference research can be distinguished. One category consists of stated opinion or behavioural-based questions regarding a hypothetical situation. An example is asking a person to rate on a response scale with 7 categories (from a very low to a very high chance) the likelihood that he or she may decide to change location should a certain road pricing measure be implemented. Although this kind of approach may be enough to obtain a valid answer to certain questions, sometimes it may be needed, for example, to gain a more precise numerical insight into the importance of certain alternative characteristics relative to each other[45] (for example, the importance of road pricing costs in location decisions of actors relative to other location or trip related characteristics). In such cases other stated preference techniques can be used in which respondents are presented with different hypothetical alternatives. In most experiments, respondents are presented different choice sets, each set consisting of different alternatives (with a minimum of two alternatives per set). These alternatives can, for example, represent different modes of transport, e.g. bus, train and taxi. Each alternative in turn consists of one or more

44 (To be) implemented measures often have different goals, ranging from reducing congestion to collecting money in general.

45 For example, to be able to determine the importance of road pricing costs in location decisions of actors relative to other location or trip-related characteristics.

attributes, which together specify the alternative. Building further on the theme of mode of transport, attribute characteristics may for example be travel time, travel costs, convenience of the transport mode, etc. Each attribute subsequently consists of two or more levels. For example, travel time by taxi is either 10 or 20 minutes, depending on the level of traffic congestion, and travel time by train amounts to 30 or 35 minutes, depending on delays. Thus, the attributes and their corresponding level values present a complete picture of the alternative. A preference in favour of this alternative can be traded off against other alternatives within a choice set. In addition, attribute levels, attributes themselves and sometimes even choice alternatives will or can vary between different response screens.

Within such stated preference experiments, respondents are asked to indicate their preference in favour of an alternative within a given choice set. The researcher can select several response options. Examples of these types of response are (Louvière *et al.*, 2001):

- The discrete choice of one option (i.e. alternative) from a set of competing ones; this measures the single most preferred option (i.e. a nominal scale), without providing information about the relative preferences among the various options.
- A complete ranking of options from most to least preferred; this response ranks all options with regard to their preference (i.e. ordinal scale), but provides no information about the degree of preference.
- Expressing degrees of preference for each option by rating them on a scale; if consumers can supply reliable and valid estimates of their degrees of preference, this response contains information about equality, order and degrees of differences or magnitudes (i.e. interval or ratio scale).
- Allocation of some fixed set of resources, such as money, trips, etc., to different available options (i.e. ratio scale).

Stated choice experiments can be seen as a special case of stated preference experiments (i.e. the first of the possible types mentioned above). Early applications of stated preference analyses were dominated by ranking techniques, largely because of the pre-eminence in market research from which conjoint experiment techniques were imported (Wardman, 1998). However, ranking procedures have often been regarded as being too difficult for respondents. Instead, it is easier for respondents to choose one option, and in addition this approach resembles the decision-making process that people, for instance travellers, are faced with more closely (Wardman, 1998). This is why nowadays a vast majority of stated preference studies in fact use a stated choice approach.

3.3.4 - Simulation models

In addition to using questionnaire-based data (i.e. of a stated preference nature), *simulation models*[46] can also be used to study the (geographical) effects due to pricing conditions ex ante (before actual implementation of the measure(s)). Land-use transport interaction models, which in an iterative way simulate the effects of changes in the transport system on the land-use system (i.e. the distribution of residential, industrial or commercial locations) and vice versa, are an example of simulation models that can be used to forecast the location effects as a result of the introduction of (road) pricing. In the case of simulation models, a choice can be made between applying a model that already exists and developing a new one. The advantage of using

46 Simulation models in general contain a behavioural model based on revealed or stated preference data.

an existing (possibly revised) model is that the effort to undertake the simulation is relatively low. The model has already been calibrated and can be used immediately. It takes time and effort to build and calibrate a new model. Nevertheless, it may be better to develop a new model when none of the existing ones will do.

Simulation models may not only be used to gain insight into a whole range of behavioural effects, they can also be used to provide input data for other simulations, for instance for computing certain 'evaluation' indicators. Geographical accessibility measures, discussed in chapter 2, are an example of such indicators. When computing accessibility effects due to road pricing, for example, travel time changes caused by behavioural adaptations (see also chapter 2, section 2.5.3.3) can be determined by using a traffic or land-use-transport interaction simulation model. An advantage of using evaluation indicators may be that there is a certain level of agreement among research experts and/or policy-makers with regard to the usefulness of (already) defined concepts such as accessibility, whereas asking 'ordinary' people to indicate changes in their accessibility due to road pricing measures may be harder because of the needed explanation to clarify the concept.

3.3.5 - Discussion and choice of methods for this thesis

Both stated preference researches and simulation models are able to give an overview of the extent to which certain groups of people or firms want to make changes in their trips and or locations under (road) pricing conditions. Stated preference data are useful to gain insight into the extent to which actors want to change their behaviour due to different pricing measures. In addition, stated preference data can be used for studying relations between dependent and independent explanatory variables. Simulation models on the other hand are suitable for forecasting effects on the basis of possibly complex interacting relations and to visualize effects for certain research areas of interest. However, a clear-cut distinction between empirical based stated preference researches on the one hand, and simulation based studies on the other hand cannot always be drawn. To simulate road pricing effects for a particular study area (in a realistic way) insight into how different variables influence each other has to be derived first. This insight can be obtained from empirical data. Moreover, empirical data is needed to calibrate and validate simulation models.

In this research (chapter 4), a simulation approach is applied to determine the sensitivity of computed geographical accessibility outcomes due to road pricing. This sensitivity is determined for different design variables that have to be operationalized when computing accessibility effects (e.g. sensitivity for the size of the value of time[47], the type of accessibility measure, etc.). As will be described in greater detail in section 3.5.1, two different simulation models are used to gain insight into the sensitivity of accessibility outcomes to varying input characteristics/values. In addition, section 4.1 describes in greater detail (than is done in this chapter) why a simulation approach is applied to the sensitivity analysis instead of computing the effects manually or by reasoning what the outcomes may look like. Finally, to assess the behavioural effects due to various road pricing measures, stated preference data (rather than a simulation study)[48] is used.

47 The ranges within which values of time vary are explored on the basis of stated preference research and are applied in the sensitivity analysis in chapter 4.

48 The study does not aim at assessing behavioural effects on the basis of a simulation model. To assess realistic behavioural effects through a simulation approach (e.g. land-use transport interaction model) relationships

Table 3.1: research methods to be used to answer the research questions (SP is acronym for stated preference)

Research question	Short clarification of research question	Research method
1	Applicability accessibility measures for modelling road pricing (RP) accessibility effects	Office-desk research (literature review) *Already answered in chapter 2*
2	Sensitivity accessibility changes due to RP and implications	Simulation approach + (SP data)
3	Behavioural changes households due to pricing	SP data
4	Accessibility and behavioural changes firms	SP data

In conclusion, research question 1 was already answered through some sort of desk research. Research question 2 will primarily be answered by applying an accessibility simulation approach. Questions 3 and 4, finally, are answered based on stated preference data only. Table 3.1 gives a schematic overview of the methods that have been or are used to answer the various research questions.

3.4 - Data considerations and empirical research

As indicated in chapter 1, section 1.1, this research focuses on pricing (effects) from a geographical perspective and is part of a larger multidisciplinary project called 'a Multi-Disciplinary study of Pricing policies In Transport' (MD-PIT). One of the important features of this multidisciplinary research has been the (mainly) joint collection of empirical data. Empirical data was derived in a number of questionnaire rounds. In each questionnaire, partners within the project team raised questions that were relevant to their particular area of interest/expertise. Additionally, substantial parts of the questionnaires were set-up together, based on common research interests.

This section describes the data used to answer the research questions. Section 3.4.1[49] deals with data needed for the accessibility sensitivity study in chapter 4. Furthermore, sections 3.4.2 to 3.4.6 describe the characteristics of the empirical study. In each section the features of one of the surveys are discussed. In sections 3.4.2 to 3.4.5 household questionnaire study characteristics are given. Section 3.4.6 describes the features of the firm questionnaire. All questionnaire studies, except the one described in section 3.4.5, were conducted together with partners within the MD-

or parameters must be adjusted because existing models may not be suitable to model realistic effects due to the introduction of a pricing measure realistically. Current models, for example, may not take sufficient differentiation in values of time for different user classes into account, nor do they commonly include perceptions and attitudes, which may affect people's behaviour under pricing conditions. Model adjustments can take place on the basis of stated preference data. However, that is something, which falls beyond the scope of this thesis.

49 Data in 3.4.1 is not specifically collected within the MD-PIT project but has been derived from another partner within the project (namely Van Amelsfort, D., Delft University of Technology and Goudappel Coffeng BV).

Table 3.2: overview of the different questionnaires used within this study

Questionnaire	Description
Household	
Household questionnaire 1A (HH1A)	Commute trip trade-offs under pricing
Household questionnaire 1B (HH1B)	Commuter opinion questions + home location trade-offs
Household questionnaire 2 (HH2)	Short and long-term behavioural changes for three trip motives
Household questionnaire 3 (HH3)	Short-term behavioural changes for shopping trips
Firm	
Firm questionnaire (FQ)	Behavioural reactions (short and long-term) of firms

PIT research[50]. The ('multidisciplinary') data were collected by TNS NIPO[51], a Dutch company specialized in collecting (and analysing) data. NIPO used a CAPI-questionnaire (i.e. computer aided personal interview) sent out to respondents selected from a large panel of Dutch people. Additionally, students constructed the questionnaire and collected the data described in section 3.4.5. For all the surveys targets were set with respect to the number of respondents required. However, no (exact) information is/was available regarding the non-response, because the fieldwork itself was carried out by people outside the MD-PIT consortium (i.e. TNS NIPO and students) and no explicit request was made to provide non-response information.

The four household surveys described in sections 3.4.2 to 3.4.5 can be characterized as follows (see Table 3.2). The two surveys discussed in sections 3.4.2 and 3.4.3 were originally constructed as one questionnaire dealing specifically with trip and location behaviour trade-offs of car commuters[52] by means of stated choice experiments. Because of the length (and the available budget[53]) this experiment was split up into two questionnaire rounds (i.e. household questionnaire 1A and 1B) with different numbers of respondents. Questionnaire 1A (section 3.4.2) was primarily concerned with studying commuter trip behaviour trade-offs under pricing conditions on the basis of a stated choice experiment. Subsequently, questionnaire 1B (section 3.4.3) on the one hand focused on studying (psychological) opinions towards different pricing measures, while on the other hand long-term location trade-offs under pricing conditions were examined by means of a stated choice experiment. Next, household survey 2 (section 3.4.4) was devoted to deriving data of intended trip pattern changes due to different pricing measures for three trip purposes: commuting, visiting and other. In addition to short-term changes, long-term changes were studied as well. The final household survey (survey 3) studied short-term behavioural changes for daily and non-daily shopping. Finally, a firm questionnaire was carried out to gain insight into the perceived accessibility changes and (short and long-term) behavioural reactions of firms due to a pricing measure.

50 Actual data collection commenced after each questionnaire was thoroughly piloted.

51 TNS NIPO have a panel of around 60,000 respondents at their disposal. From this panel, car commuters facing regular congestion problems were selected.

52 The motivation for selecting car commuters is given in section 3.4.2.

53 The second part (HH 1B) was conducted among fewer respondents than the first part (HH 1A), for budgetary reasons.

Because the main part of the questionnaire studies is of a multidisciplinary origin, not all data parts are used within this research. Survey characteristics in this section are, therefore, described following a certain structure. All 'survey-based' sections (3.4.2 to 3.4.6) begin with stating the goals of each survey in general (i.e. not only for this thesis). Subsequently, data characteristics are provided. At the end of each section a summary is given regarding which data is used to answer what (part of a) research question within this research. Finally, section 3.4.7 provides a summarizing overview of the connections between survey data and research questions. For a total overview of all variables and response scales in the questionnaires, see Appendix B.

3.4.1 - Accessibility simulation input data

To model geographical accessibility effects due to road pricing policies a study area has to be selected. As described in section 2.4.3, traffic (and thus accessibility) effects in general play a role specifically at a regional level. Therefore, a study area with a regional size is preferred for the sensitivity analysis in chapter 4. Moreover, an important reason to implement a pricing policy is to reduce traffic congestion by influencing the short and long-term behaviour of people. As a consequence it may be interesting to study the sensitivity of accessibility outcomes on the basis of a research area with traffic congestion.

In short, the preferred study area has a regional size and is an area in which traffic congestion occurs. Generally speaking, the selection of a research area is not a problem with regard to relatively standard distance or travel time based geographical accessibility studies. Digital area and road maps are available for whole of the Netherlands. Yet, GIS-simulation tools with which geographical accessibility effects can be computed currently cannot cope with changing traffic conditions due to policy measures such as road pricing. These changing traffic conditions in turn influence accessibility via travel time changes (see section 2.5.3.3). To obtain a realistic insight into the sensitivity of accessibility changes due to road pricing, it is considered important to include travel time changes. By doing this, one may, for example, get insight at which price levels accessibility increases/decreases for certain types of actors (i.e. insight into trade-offs between costs and benefits). To be able to include 'realistic' traffic effects a traffic simulation model is needed. For that reason, a 'hybrid' modelling approach is adopted in which output data from a traffic simulation model provided by one research partner[54] is used as input data for a GIS accessibility application (for details, see section 3.5.1 and section 4.2.1). This approach limits the available choice of study areas because the research area must be the same in both types of models. In the end we selected a research area that met our primary criteria and that was also suitable to be used in the traffic assignment model.

At the time the study area had to be selected, only one regional study area with (some) traffic congestion was available. The area is part of the Dutch Province of Noord-Brabant (southern part of the Netherlands) (see figure 3.2). The east-west length amounts to approximately 50 kilometres. In the north-south direction the size of the research area is somewhat smaller (approximately 30 kilometres). Two major cities are positioned within the boundaries of the area. The bigger of the two is Eindhoven with about 208,000 inhabitants, the smaller one is Helmond, with a population of about 86,000. Several motorways cross the area, all converging in Eindhoven. The motorways in the area are notorious for their traffic jams. The study area in the simulation study

54 Van Amelsfort, D., Delft University of Technology and Goudappel Coffeng BV.

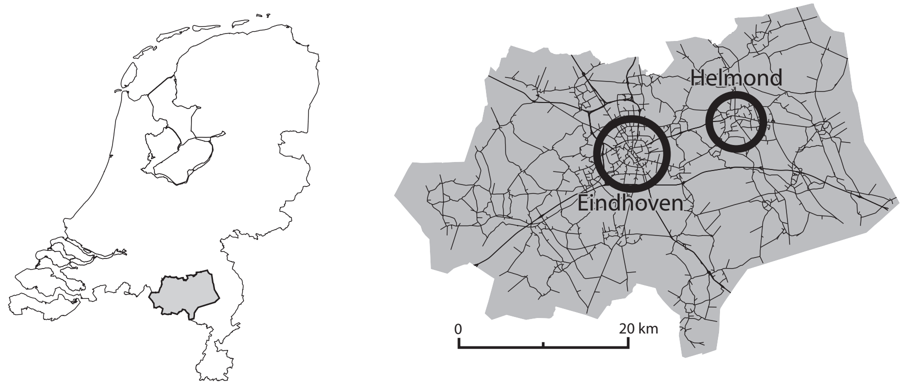


Figure 3.2: study area. Left: study area shaded in grey as part of The Netherlands. Right: study area with network links and major cities

contains 441 feed points. These points are used as points where the traffic can enter ('feed') the digital road network. An advantage of the feed link approach is that the network needs no further adjustments, irrespective of the zoning system used. All zones tap to the network via the feed point. A disadvantage is however, that by using feed points realism decreases (i.e. simplification of reality). The total area is divided into 2378 residential zones.

On the basis of this regional study area the sensitivity of accessibility changes due to road pricing is studied in chapter 4. This sensitivity study is aimed at providing an answer to research question 2.

3.4.2 - Household questionnaire 1A: short-term trip trade-offs (stated choice)

The principal aim of this multidisciplinary questionnaire was to derive data to gain insight into trade-offs car commuters make between road pricing fees and fuel costs, travel time, departure/arrival time, reliability of time, route length and the mode of transportation.

This first household questionnaire was held among 1,115 respondents. Only car commuters who faced traffic congestion on a regular basis (i.e. at least 2 times a week with a minimum delay of 10 minutes) were selected. Car commuters were chosen because they are the kind of drivers who face congestion problems regularly, which means they are directly affected by pricing measures aimed at reducing congestion. Respondents were not chosen on the basis of the region in which they live. However, because only regular 'congestion-drivers' were selected, and the most severe traffic problems occur especially in the western (i.e. the provinces of South and North Holland, Utrecht) and southern part (i.e. North Brabant) of The Netherlands, around 70 percent of the respondents comes from these regions. Only around 5 percent of the respondents in contrast live in the northern part of The Netherlands (i.e. provinces of Groningen, Friesland, Drente).

An initial analysis showed that a random sample would lead to a relatively low share of lower income workers (i.e. annual gross household income of less than € 28,500). Because we wanted to measure the effects of road-pricing measures on lower income households as well, these groups were relatively over-sampled. The 1,115 car commuters were asked to take part in a questionnaire that basically consisted of two parts:

- Questions regarding general socio-economic and demographic explanatory variables; additionally, trip related characteristics needed to tailor a stated choice experiment were asked.
- A stated choice experiment in which respondents were asked to trade-off several trip related characteristics, among other things a road pricing fee.

The respondents were confronted with a stated choice experiment consisting of four alternatives per choice set. In each set the respondents had to divide 10 trips over all alternatives, representing the number of times they would prefer or choose a certain alternative. The respondents were allowed to freely distribute the 10 trips over the four alternatives, meaning that, for example, all 10 trips could also be adjudged to one alternative. An overview of the set-up of the choice sets shown within the experiment is given in Table 3.3.

Alternatives A to C were all car alternatives. The values presented to the respondents were tailored on the basis of their current commute trip length and their preferred departure time both of which were derived from the first part of the questionnaire. Alternative D was the public transport alternative, specified on the current public transport travel time indicated by the respondents, or based on (a multiplication of) the free-flow car travel time when the public transport commute time was unknown. Although there were differences between the values of the variables for each alternative between choice sets, the overall image remained the same. Alternative A always represented the alternative with the highest road pricing fees but with the most favourable conditions with regard to travel time and arrival time. Alternative B in general had a lower road pricing fee than alternative A, but travel conditions were less attractive (i.e. higher travel times due to congestion and higher uncertainty). Subsequently, alternative C could be regarded as the detour or alternative route scenario. Travel distances were longer than

Table 3.3: set-up of the choice set (source: Van Amelsfort and Bliemer, 2005)

Alternative A	**Alternative B**	**Alternative C**	**Alternative D**
Mode: car *Trip length: x km*	*Mode: car* *Trip length: x km*	*Mode: car* *Trip length: x km*	*Mode: PT*
Total travel costs: Fuel costs: Charge:	*Total travel costs:* Fuel costs: Charge:	*Total travel costs:* Fuel costs: Charge:	*Trip length: x km* *Total travel costs:*
Departure time:	*Departure time:*	*Departure time:*	*Departure time:*
Travel time between … and … min	*Travel time between … and … min*	*Travel time between … and … min*	*Travel time:*
of which free-flow: … min min. congestion: … min max. congestion: … min	of which free-flow: … min min. congestion: … min max. congestion: … min	of which free-flow: … min min. congestion: … min max. congestion: … min	*Arrival time*
Arrival time between … and …	*Arrival time between … and …*	*Arrival time between … and …*	
Number of trips:	*Number of trips:*	*Number of trips:*	*Number of trips:*

in options A and B. However, changes in arrival time were smaller than in alternative B (see also Van Amelsfort and Bliemer, 2005). Finally, option D always represented the public transport alternative.

In constructing choice experiments in general, the issue of orthogonality plays an important role. An orthogonal design implies that attribute (variable) effects, such as travel time or road pricing fee, can be estimated independently (without correlation) in models (see section 3.5.2 for some popular types of model estimations that can be carried out on the basis of stated choice data). Furthermore, orthogonal designs provide a systematic guide for varying attribute levels within and between alternatives and choice sets correctly.

There are two types of orthogonal design types: (full) factorial designs and fractional factorial designs (see Louvière, 1988; Louvière *et al.*, 2000). Within full factorial designs all attribute levels are orthogonal (i.e. truly independent) to one another, both within and between alternatives (Louvière *et al.*, 2000). Factorial designs, therefore, make it possible to estimate statistical effects or parameters of interest completely independently of one another (in models). This means that all order effects, such as main, and all two-way and higher order interactions, can be estimated independently. Main effect independence in this case refers to 'zero value' correlations between attributes within, between and over choice alternatives. If main effects and two-way interaction effects are independent, this refers to the fact that combined effects of attributes (for example travel time * road pricing fee) have a zero design correlation with the main effects (the attributes), but also with all other possible two-way interactions. This process can be continued for interactions that are even higher than second-order interactions. Notwithstanding the statistical advantages produced by complete factorials, such designs are applicable only for small problems involving either small numbers of attributes or levels, or both (Louvière *et al.*, 2000). Nevertheless, most stated choice experiments are too large to develop a full factorial design. As a consequence, Louvière *et al.* (2000) state that in many cases one should use (smaller) main effect designs, because models derived from these designs often result in accurate predictions[55] in attribute regions of greatest interest, even if their parameters are biased.

As the number of possible combinations in complete factorial designs are practically too large, complexity can be reduced by using fractional factorial designs. Fractional factorial designs involve the selection of a particular subset or sample (i.e. fraction) of complete factorials, such that particular effects of interest can be estimated as efficiently as possible (Louvière *et al.*, 2000). Different types of fractional factorial designs can be constructed on the basis of a trade-off between complexity and the level of detail required (for an overview of design strategies, see Chrzan and Orme, 2000). The simplest fractional factorial would be an orthogonal main effects design. Designs incorporating orthogonality of effects higher than the two-way interactions are hardly ever applied.

For the construction of the choice experiment in this first questionnaire, a (fractional factorial) main effects design was used. The experiment contained 13 attributes with four levels and two

55 Main effects typically account for 70 to 90 percent of explained variance; two-way interactions typically account for 5 to 15 percent of explained variance; higher order interactions account for the remaining explained variance (Dawes and Corrigan, 1974, derived from Louvière *et al.*, 2000).

attributes with two levels. Varying attributes over four levels offers the opportunity to test for non-linearities in attribute valuations. The total constructed orthogonal main effects design resulted in a design of 44 treatments or choice sets. To reduce the task complexity of the respondents the 44 treatments were appointed to four different blocks of 11 choice sets. The four blocks were randomly assigned to respondents. Thus, each respondent was presented with only 11 choice sets (with four alternatives). The number of choice sets respondents can practically handle within a questionnaire depends also on the complexity of the experiment. However, Adamowicz *et al.* (1998) state that respondents can be expected to handle as many as sixteen choice sets. Finally, the 11 sets within a block were presented randomly to prevent as much as possible any of the (unforeseen) learning and inertia effects that may occur due to a certain sequencing of offered choice situations, leading to correlated choice situations (see also section 3.5.2). For a more detailed explanation or other overviews of the construction of the experiment (including level variations) see Van Amelsfort and Bliemer (2005) or Tseng *et al.* (2005).

Data from the stated choice experiment is used within this thesis to estimate values of time that are used in the accessibility sensitivity study in chapter 4. Thus, this data helps to be able to answer research question 2.

3.4.3 - Household questionnaire 1B: opinions and long-term (location) trade-offs

The aim of this multidisciplinary survey was to derive data to gain insight into car commuters' (psychological) opinions regarding various types of pricing measures and revenue uses, into car commuters' perceived accessibility change due to a pricing measure and, finally, into the trade-offs that car commuters make between pricing-related travel costs, travel time and location related variables in residential location decisions.

As described in the introduction of section 3.4, the first household questionnaire (among commuters) was intended primarily to be set-out in the field at once. However, due to the length of the first household questionnaire and budgetary constraints regarding the fieldwork, the decision was made to split up the questionnaire into two parts: household questionnaire 1A and 1B. Characteristics of questionnaire 1A were already given in section 3.4.2. The stated choice experiment in questionnaire 1A was separated into four blocks of 11 choice sets to reduce the complexity. To mitigate the effect of this separation the stated choice experiment (with 11 sets) was shown to a relatively large group of respondents (i.e. 1,115). Such high numbers were not needed for the questions in questionnaire 1B, which meant we were able to cut data collection costs. In total 564 car commuters facing traffic congestion regularly answered the second questionnaire. 515 of them were selected from questionnaire 1A. Furthermore, 49 car commuters facing congestion at a regular basis (i.e. at least 2 times a week with a minimum delay of 10 minutes) and with a relatively lower income (i.e. annual gross household income of less than 28,500 euro/year) were added, to avoid under sampling of these lower income groups. The questionnaire consisted of the following parts:

- Questions regarding general socio-economic and demographic explanatory variables;
- Household (psychological) opinion questions towards various pricing measures and revenue uses;
- Questions about peoples' perceptions with regard to them being better or worse off due to road pricing which may be used to approximate perceived accessibility changes of households due to road pricing;

- A stated choice experiment in which respondents were asked to trade off several trip characteristics (among which a road pricing-related variable) against location and house related features.

With respect to the second point mentioned above, each respondent was presented with three different types of measures: (i) a bottleneck charge, (ii) a flat kilometre charge differentiated on the basis of the weight of the vehicle and (iii) a flat kilometre charge. For each measure different variants were created, only one of which was randomly selected and presented to a respondent for every case. Four bottleneck options were constructed varying (particularly) on the level of time-specificity of the toll. The second charge, the differentiated kilometre charge on the basis of the car weight, was divided into seven alternatives on the basis of the type of revenue use. For the third measure, the flat kilometre charge, nine alternatives were created (i.e. three price levels, three types of revenues use). After a measure was shown to the respondents, they had to answer several opinion-related questions on a 7-point ordinal (Likert) scale. This information was not used, however, within the context of this thesis and therefore will not be described extensively here. For an elaborate overview of the characteristics and analyses of those data, see Ubbels and Verhoef (2005).

In addition, two questions were asked to approximate the perceived accessibility change of car commuters due to the introduction of a kilometre charge. These two questions varied with respect to the height of the charge and the time (in congested conditions) that would be gained by the charge. After seeing the charge, respondents were asked to indicate on a 7-point ordinal (Likert) scale whether they felt they would be better or worse off as a result of the kilometre charge. For more details and the analyses, see Appendix D and section 4.5.

To investigate the relative influence of trip and more location-related variables in the actual residential location choice a stated choice experiment was conducted (see Table 3.4). Although road pricing may also play a role in the decision which job to accept, this thesis is limited to investigating the role of road pricing in the residential location choice. The influence of the work location however, is considered (implicitly) by taking into account the commuting travel time and travel costs within the choice experiment. Every respondent was presented nine hypothetical choice situations consisting of two alternatives. Each alternative was described by six attributes (number of bedrooms, monthly rent or mortgage costs of the house, the location[56], the free flow travel time, congested travel time and travel costs[57]) at three levels. Using a three by six (i.e. three levels, six attributes) 'standard' design of 27 treatments (see Kocur *et al.*, 1982), all main effects (and three second-order effects) can be estimated independently. A three-level variation was chosen because it is the minimum requirement for testing for non-linearity of the attribute valuations. The 27 treatments were divided into three blocks of nine treatments to reduce task complexity and questionnaire length. Each respondent was presented one randomly selected block of choice sets. The actual values of the attributes were tailored to the specific situation of the respondents, for instance on the basis of the actual commuting distance and type of dwelling. In contrast to the stated choice experiment described in section 3.4.2, respondents only had to choose the one option (among two) they preferred.

56 With regard to location, three levels were distinguished: (large) city, medium sized city, small village/rural area.

57 Travel cost was further divided into road pricing and fuel costs.

Table 3.4: set-up of the location choice set

Alternative A	**Alternative B**
Number of bedrooms: …	Number of bedrooms: …
Monthly housing price (rent or mortgage): …	Monthly housing price (rent or mortgage): …
Location/environment: …	Location/environment: …
Commute travel time one-way (min) free flow travel time: … extra travel time in traffic congestion: … total travel time: …	Commute travel time one-way (min) free flow travel time: … extra travel time in traffic congestion: … total travel time: …
Commute travel costs one-way (euro) pricing fee one-way: … fuel and other variable costs: … total costs: …	Commute travel costs one-way (euro) pricing fee one-way: … fuel and other variable costs: … total costs: …
Total travel costs per month (5-day workweek and 2 trips/day): …	Total travel costs per month (5-day workweek and 2 trips/day): …
Choice: …	…

The stated choice experiment data is used to answer part of research question 3. More specifically, the data allowed us to study the importance of a (road) pricing fee in the residential location choice of households when the decision to relocate has been taken due to road pricing or for another reason.

In sum, two topics of this questionnaire are used within this thesis: (i) the perception with regard to being better or worse off (see Appendix D and section 4.5) and (ii) the stated choice experiment. The stated choice experiment is used to partly answer research question 3 in chapter 6 (i.e. the influence of road pricing on the residential location choice when the decision to relocate has already been made).

3.4.4 - Household questionnaire 2: short and long-term behavioural changes

The aim of this multidisciplinary survey at project level was to derive data to be able to gain insight into short (i.e. trip-related changes) and long-term (i.e. work and residential location) behavioural changes due to different types of pricing, and to observe attitudes towards different types of pricing measures.

The survey was held among 562 respondents, 288 of which were commuters who drive to work by car two times or more per week and face a delay of 10 or more minutes at each trip at least twice a week. The 288 persons were selected from the respondents who also answered the first questionnaire (section 3.4.2). The other 274 were respondents who (or whose household) owned a car. They were added to broaden the scope of the study and to be able to study (behavioural) effects due to pricing measures for groups other than regular car commuters (in congestion) as well. As is the case for the questionnaires described above, approximately 70 percent of the respondents live in the Western provinces and North-Brabant because congestion problems in these regions of The Netherlands are most severe. No attempt was made to 'oversample' respondents from Northern regions of the country.

Different kilometre charges were presented to the respondents (see Table 3.5). The design of the three kilometre charges consisted of six, two and again six alternatives respectively. Within each kilometre charge category (three in all) one alternative was selected. Thus, in total three kilometre charges were shown to each respondent. After the presentation of each of the three kilometre charges, questions were asked that could be categorized into three classes:

- Questions regarding short-term behavioural (i.e. trip-related) changes due to the kilometre charges.
- Opinion questions regarding the kilometre charges (such as justness, acceptability, etc.).
- Questions regarding long-term (location) changes due to the kilometre charge.

In the case of the short-term trip changes respondents first had to indicate, after seeing the price measure, whether they would adjust their car trip behaviour over a period of four weeks. If they answered they wanted to make more trips, they were also asked how many more car trips they would want to make (on a four week basis). If respondents indicated to make changes in their current car trip pattern they were asked to state the number of current car trips they wanted to adjust, again over a four week period (i.e. data on a ratio scale). Subsequently, respondents had to divide the number of 'to be adjusted' current car trips over several options (for example, drive more often by another mode of transportation; see chapter 5, section 5.2 for more details). The third option respondents had was to change nothing.

Table 3.5: different pricing measures and variants within the questionnaire

Measure	Alternative
1. km charge (flat)	A: 3 € cent, abolishment of car ownership taxes B: 6 € cent, abolishment existing car taxation (purchase and ownership) C: 12 € cent, abolishment existing car taxation and building new roads D: 3 € cent, revenues used for lowering income taxes E: 6 € cent, revenues used for lowering income taxes F: 12 € cent, revenues used for lowering income taxes
2. km charge	A: 2 € cent with a morning and evening peak time charge (time dependent and stepwise) B: differentiated according to weight of the car, revenues used to abolish existing car taxation (4, 6, 8 € cent for respectively light, medium weight and heavy cars)
3. km charge (time-differentiated)	A: 2 € cent outside and 6 € cent within peak periods, abolishment of car ownership taxes B: 4 € cent outside and 12 € cent within peak periods, abolishment existing car taxation C: 8 € cent outside and 24 € cent within peak periods, abolishment existing car taxation and building new roads D: 2 € cent outside and 6 € cent within peak periods, revenues used for lowering income taxes E: 4 € cent outside and 12 € cent within peak periods, revenues used for lowering income taxes F: 8 € cent outside and 24 € cent within peak periods, revenues used for lowering income taxes
4. cordon charge	A: 5 € for entering city of min. 40,000 inhabitants, revenues used for lowering income taxes B: 5 € for entering city of min. 40,000 inhabitants, revenues used for improving quality of public transport in region C: 5 € for entering city of min. 40,000 inhabitants, revenues used for improving quality of public transport in whole country
5. cordon charge	8 € for entering city of min. 40,000 inhabitants, revenues used for lowering income taxes

In all, this procedure was repeated for three types of kilometre charge and three different trip purposes: commuting, social (visiting) and other trips. Commuting was chosen because commuters represent an important group of travellers on regular working days. Furthermore, especially car commuters face congestion problems regularly and thus are directly affected by pricing measures aimed at reducing congestion. Social (visiting) trips were selected because they occur on quite a regular basis and as a consequence are easy to 'imagine' for respondents. Other trip purposes than commute or social were combined under one category 'other trips'. Business trips were not selected as a separate category because the expectation is that road pricing will not influence their trip pattern to a large extent. Moreover, other separate purposes were not selected due to their relative lower importance, budget constraints and due to researcher's preferences within the MD-PIT project. Respondents only had to answer questions regarding the kind of trips (i.e. the trip purposes) they actually made by car (with a minimum of one trip per week). In addition, 'opinion' questions were only asked once for every kilometre charge. These opinion-related questions were not used to answer research questions in our (geographical) thesis. At most, we used them as explanatory variables with regard to certain behavioural changes due to pricing.

Only employed respondents (in total 465 of 562) were asked to indicate the probability of them relocating due to a road pricing measure because of the important relationship that exists in general between job-related and residential locations (see Hanson and Pratt, 1988). 284 of them were regular car commuters facing congestion problems. The other 181 respondents were working car owners. As was the case with the 'opinion' questions, relocation questions were only asked once for every kilometre charge. Respondents had to indicate the probability that they would relocate to another dwelling (closer to work) or look for another job (closer to home) on a 7-point Likert-scale ranging from 'highly unlikely' to 'highly likely'. Although short-term and long-term behavioural effects and attitudes were determined for three kilometre charges, the length of the questionnaire was limited for budget reasons and to prevent respondents from getting too much information (e.g. respondent fatigue). Therefore, in the case of the cordon charges (i.e. measure 4 and 5 in Table 3.5) questions were limited to relocation questions and to one acceptance question. The cordon charges were presented to working respondents driving to work by car at least once a week, living and/or working in a medium-sized or large city[58] and leaving the city boundary at least once every time they commute. In total 262 respondents met these requirements, 195 of them belonging to the group of regular congestion drivers and the remaining 67 fitting into the category of workers with cars.

To summarize, in particular two parts of this questionnaire are used within this thesis: (i) the short-term behavioural (trip) change questions (i.e. ratio scale) and (ii) the relocation questions (i.e. ordinal scale). Data from both questions (in combination with data from section 3.4.3) are used to answer research question 3.

3.4.5 - Household questionnaire 3: short-term behavioural changes (shopping)

The aim of this survey was to derive data to gain insight into changes in people's current daily and non-daily shopping car trip pattern due to pricing measures.

58 In this thesis a city with 40,000-100,000 inhabitants is considered a medium-sized city; a city with more than 100,000 inhabitants is characterized as a large city.

This survey was *not* undertaken within the multidisciplinary context of the project. Students from the Delft University of Technology in the Netherlands designed the questionnaire and also collected the data[59]. In total the survey was held among 280 respondents. Respondents were persons who use their car at least once a week for daily shopping purposes or at least once a year for non-daily shopping in another city (than the one in which they live). The purpose 'shopping trips' was chosen because it forms a valuable extension to the data described in section 3.4.4, in which the trip purposes had to be limited to three (due to budget constraints). In total, four questionnaire versions were created, which varied with respect to the pricing measure that was applied. Two types of pricing measures were developed (see Table 3.6): a time-differentiated kilometre charge and a cordon charge. Furthermore, within each price measure category two versions were created: a low and a higher charge level. One price measure was presented to each respondent, in such a way that ultimately the 280 respondents were quite evenly distributed among the four versions.

No demands were set with respect to the geographical dispersion of respondents (i.e. where they live). All people who met the criteria described above, possessed a car and were willing to cooperate were included. In most cases the students approached people in city centres. Because the majority of the students lived in Delft or within the vicinity, most respondents were interviewed in this area. Respondents were also asked to fill in the zip code of their home address, which made it possible to assess afterwards were respondents live(d). Such an analysis showed that indeed the far majority of the respondents lived in or in the vicinity[60] of Delft.

The general structure of all the versions was as follows:

- General (characteristic) questions about current frequency, time and place of daily and non-daily shopping trips.
- Introduction of one of the four price measures from Table 3.6.
- Questions regarding changes in the car trip pattern for daily and non-daily shopping trips (including shopping location changes). Answers had to be given in the form of the number of shopping trips by car to be adjusted (i.e. ratio scale).
- General socio-economic and demographic questions.

Although the set-up of all four versions of the questionnaire basically was the same, there were some small differences depending on whether a kilometre or cordon charge was presented to the respondent. To make the cordon charge imaginable and realistic for the respondents it was presented as being implemented around the four largest cities within The Netherlands[61]. Therefore, respondents were only asked to indicate changes in their daily and non-daily shopping pattern by car to (one or more of) these four cities. In the case of the kilometre charge, implemented nationwide, daily shopping trip questions were not related to a specific city. However, non-daily shopping trip changes were only asked for car trips made for shopping in another city (than the one where the respondent lived) to guarantee that shopping distances are substantial enough to

59 The questionnaire construction and data collection was part of a bachelor course for students from the faculty of Technology, Policy and Management at Delft University of Technology in The Netherlands in 2004.

60 Respondents in the 'vicinity' of Delft in most cases live(d) in Rotterdam and The Hague.

61 These cities are Amsterdam, Rotterdam, The Hague and Utrecht.

Table 3.6: different pricing measures and variants within the questionnaire

Measure	Alternative
1. km charge	A: peak periods (7-9 and 17-19 hr) 10 € cent/km; outside peak + weekend 5 € cent/km B: peak periods (7-9 and 17-19 hr) 20 € cent/km; outside peak + weekend 10 € cent/km
2. cordon charge	A: peak periods (7-9 and 17-19 hr) 8 €/passage (only city inwards); outside peak + weekend 4 € B: peak periods (7-9 and 17-19 hr) 12 €/passage (only city inwards); outside peak + weekend 6 €

make sure the kilometre charge had any influence and to make comparisons between the cordon and kilometre charge possible.

The data can be seen as an additive to the data described in section 3.4.4, where behavioural changes were studied for three trip purposes: commuting, visiting and other. Data derived from this questionnaire provides insight into behavioural reactions regarding one other important trip purpose: daily and non-daily shopping. Within the questionnaire described in section 3.4.4, this latter purpose can be seen as fitting into the relatively undefined trip class of 'other trips'. Moreover, in addition to gaining insight into trip changes with respect to another trip purpose (i.e. shopping) a more typical geographical aspect, i.e. the extent to which people want to change their shopping location, can also be studied on the basis of this questionnaire data.

In sum, this non-multidisciplinary study is used to gain insight into behavioural (trip and to some extent location) changes in daily and non-daily shopping due to different pricing measures. Data on the behavioural changes were measured on a ratio scale, and data are used to (be able to) give a more detailed answer to research question 3 than is possible on the basis of the other data only.

3.4.6 - Firm questionnaire: short and long-term behavioural changes

The aim of this multidisciplinary survey was to derive data to be able to gain insight into the behavioural changes of firms, such as trip, location and employee compensation changes, due to a pricing measure on the one hand, and into opinions and changing accessibility perceptions on the other.

The survey was conducted among 480 firms operating in the business service or industrial sector. These types of firms were selected first of all because firms within these categories are relatively autonomous in their behaviour and policy. Within the limits of laws and general agreements they can decide for themselves to what extent they want to compensate employees or want to adjust their trip behaviour. Moreover these firms, especially firms within the service sector, are (relatively) free to settle where they like[62]. Therefore, they are able to indicate behavioural changes due to a pricing measure. For those same reasons, public organizations or firms working within the retail sector were not included. Firms within the public sector, for example, often work within nationwide public policy frameworks (e.g. with regard to cost compensations) and even more important, public organizations (and also firms within the retail sector) are often interconnected

62 Of course the freedom of choice is to a large extent defined by employee locations (e.g. employee pools) and links with and locations of other firms or organizations.

with their current locations (i.e. cities, regions). For example, a town hall cannot be moved to an entirely different city just because of a pricing measure.

In addition, companies within the transport sector were not taken into account. Although in itself it would be interesting to study behaviour changes of these firms, that kind of firms is quite likely to be influenced by a pricing measure in a different way. Firms operating in the transport sector, for example, to a lesser extent earn their money in the place where they are located than companies operating in the business sector. As a consequence, both types of firms will be influenced in different ways by pricing. The choice in favour of business sector and industrial firms rather than firms operating in the transport sector was made because there are more companies in the former category in The Netherlands and more people work for those types of firms (Dutch Chamber of Commerce, 2005). Industrial and business sector firms thus take an important position within the Dutch firm pool. Another, more practical, reason to choose firms in the business, service and industrial sectors was that response requirements could be met more easily due to the higher number of firms within these sectors. Finally, we selected only firms with at least employed 20 employees, because small firms are often thought to have a less clear employee policy, which would make it harder for them to answer our questions. Moreover, small firms are often connected to a specific location or city, which means that the likelihood that they will want to relocate is affected by their ties in the local community. This makes studying relocation effects for them less interesting. Firms in this research were selected from a nationwide panel of the data collecting party (TNS NIPO). Compared to the household datasets described above, the firms in this dataset are more equally spread over the different regions in the country. Around 30 percent of the firms are located in the north and also 30 percent in the west. The remaining 40 percent is rather equally divided over the eastern and southern regions.

The questionnaire consisted of the following parts:

- Questions regarding the general characteristics of the firms.
- Some questions about opinions and perceptions.
- Questions about current firm behaviour.
- The description of the pricing measure.
- Questions concerning changes in firm behaviour and perceptions.
- Questions about the most recently recruited employee.

Examples of the questions about perceptions and opinions were questions regarding the current perceived accessibility of firms and how important they find several settlement-related factors. Subsequently, current firm behaviour questions aimed at two things: first of all to gain insight into the current compensations employees receive; and secondly, to learn more about their current relocation probability (i.e. within 2 years).

One pricing measure was shown to each respondent (see Table 3.7). The initial set-up of the questionnaire included a kilometre as well as a cordon charge. For budgetary reasons and to keep the length of the questionnaire within acceptable limits, however, the cordon charge was left out. A kilometre charge instead of a cordon charge was chosen, because it is more likely that a kilometre charge will be implemented in The Netherlands.

Table 3.7: description pricing measures within the firm questionnaire

Measure	Characteristics
kilometre charge	4 € cent outside and 12 € cent within peak periods, revenues used for lowering income taxes

Transport-related costs are likely to form only a small part of the total operational costs of most firms (see section 2.6.4.2). As a result, their behavioural adaptations may be low. In order to be able to find small (significant) effects the choice was made not to differentiate too much within the set-up of the questionnaire. This is an important reason why only one kilometre charge alternative was selected. The charge is the same as measure 3E in Table 3.5. This measure was chosen because it is quite a realistic measure[63] with an average price level. Additionally, the overlap between the measures in both the household questionnaire (section 3.4.4) and the firm questionnaire gives the opportunity to study whether expected employee compensations (by households) are in line with what employers are willing to give. This latter aspect, however, is not explicitly studied within this research.

After the description of the pricing measure, questions regarding behavioural changes were asked. The changes that were measured are changes in trip behaviour, in employee compensations and in settlement locations. In addition to these behavioural changes, several questions relating to firms' perceived accessibility as well as to changing settlement factor scores were asked. Response scales were made uniform for almost all behavioural (change) questions: answers could be given on a 7-point ordinal (Likert) scale. Finally, the questionnaire contained some questions related to the most recently recruited employee. This latter category of questions is not used within this thesis but is analyzed by another research partner[64].

In sum, several topics of this questionnaire are used within this research. First of all perceived accessibility changes due to the kilometre charge are used to answer part of research question 4. In addition, data derived from questions regarding short-term (trip) and long-term (location) behavioural changes and questions concerned with employee compensations are also used to answer research question 4.

3.4.7 - Overview of the link between data and research questions

A summarizing overview of the data used to answer research questions is presented in Table 3.8. Research question 1 has already been answered on the basis of literature (see sections 2.4 and 2.5). To answer research question 2, which focuses on the sensitivity of accessibility changes, a study area has been selected that was named after the largest city within the area. In addition, value of time ranges to be applied into the sensitivity analysis are explored on the basis of the stated choice experiments in HH 1A (i.e. short-term value of time) and HH 1B (long-term value of time). The household behavioural effects (i.e. research question 3) are studied on the basis of survey HH 2 (for three trip motives) and HH 3 (for shopping trips). Additionally, the stated choice experiment in HH 1B is used to gain insight into location trade-offs under pricing conditions. Finally, the firm-based research question (question 4) is answered on the basis of the firm questionnaire.

63 Such a time-differentiated kilometre charge is also quite in line with the proposals of a policy advisory commission regarding pricing policies in transport (Nationaal platform anders betalen voor mobiliteit, 2005).

64 The Free University (VU) in Amsterdam analyzes these particular data.

3.5 - Analytical techniques

To analyze the data described in section 3.4 and answer the research questions, analysing techniques are needed. This section focuses on explaining the most important techniques used to answer the questions. Section 3.5.1 describes some features of the simulation models that are used for the accessibility simulation study. Sections 3.5.2 to 3.5.5 explain four statistical analytical techniques that are applied within the thesis: discrete choice, ordered regression (probit) analyses and Poisson and Tobit regressions. More conventional and well-known techniques used, such as frequency analyses, T-tests, ANOVA, cluster and factor analyses are not explained in this chapter. In addition to describing the analytical techniques, each section also links the technique to the research question(s) being answered on the basis of using that analysis approach. Finally, section 3.5.6 gives a summarizing overview of the links between the analytical techniques and the research questions.

3.5.1 - 'Hybrid' simulation approach

To compute geographical accessibility for larger areas, simulation applications are needed, as was described in section 3.4.1 (see also section 4.1, which explains in greater detail why a simulation approach is needed and why the effects are not only deduced or computed by hand). Flowmap is a GIS application that can be used to *display interaction data*, like commuting and migration flows and for *interaction analyses,* like accessibility analysis, network analysis, and interaction modelling (Zwakhals *et al.*, 2000). Flowmap is used as analysing technique to give an answer to research question 2. Three important reasons for choosing Flowmap can be given. First of all, the GIS-application Flowmap is capable of computing geographical accessibility at the preferred regional scale level by using aggregate accessibility measures (e.g. contour or potential measures) (see also section 2.4.3). Secondly, files such as study area maps can be easily transformed between Flowmap and other well-known GIS tools, such as ArcView. The third reason is a practical one. Within the department of Human Geography at Utrecht University we have direct access to source codes in case we needed to make adjustments to the model.

Flowmap basically needs two types of input to assess accessibility: opportunity locations and a road network. Opportunities are for example jobs. Accessibility is determined by how easy it is to reach opportunities via the road network. This ease is often expressed in terms of resistance or impedance. Flowmap is capable of using 'static' impedance attributes of different kinds, such as

Table 3.8: empirical data to be used to answer the research questions

Research question	Short clarification of research question	Empirical data
1	Applicability of accessibility measures for modelling road pricing (RP) accessibility effects	Not applicable *The first research question was already answered in chapter 2 primarily on the basis of literature.*
2	Sensitivity of accessibility changes due to road pricing and implications	Study area 'Eindhoven' + HH 1A en HH 1B (stated choice: value of time estimation)
3	Behavioural changes households due to pricing	HH 1B (stated choice) + HH 2 (behaviour) + HH 3 (shopping behaviour)
4	Accessibility and behavioural changes firms due to pricing	Firm questionnaire (FQ)

travel time or distance. However, the program is not able to compute changes in road network impedances due to certain policy measures. As was described in section 3.4.1, acknowledging possible impedance changes is important for a realistic assessment of the sensitivity of accessibility effects due to a road pricing measure. Road pricing measures are aimed at reducing travel times (or increasing travel time reliability) in periods and on places where congestion problems occur. These travel time changes in turn influence accessibility. Traffic simulation assignment models can provide insight into the travel-related behavioural effects of road pricing. These traffic model outputs (in the form of link travel times), before and after the introduction of a pricing measure are then used as input for the sensitivity analysis in chapter 4.

Different types of traffic assignment models have been developed over time. Models can be classified, for example, according to the level of detail with which they present the system to be studied: microscopic (high detail), mesoscopic (mixed detail) and macroscopic (low detail) (TRB, 1994). Microscopic traffic models simulate the behaviour of individual drivers and thus are detailed. Macroscopic models, on the other hand of the spectre, model at the level of traffic flows. The former types of simulation models are generally applied in lower scale applications, such as the simulation of traffic patterns on small-scale local networks. However, because of improved computational power of computers, microscopic models nowadays are sometimes applied to larger networks too (see, for example, Cohn *et al.*, 2003). Macroscopic models perform well on larger scale networks, such as regional networks, and therefore could be applied to estimate traffic effects due to pricing on a regional level.

In addition to the classification used above, an important distinction between assignment models is whether they are static or dynamic. Static models assign traffic to a road network at one instant, whereas dynamic models use different time steps. Dynamic traffic assignment models are preferred because they can take account of blocking back effects, which may lead to blockages of important links or nodes in a network. Thanks to increased computer abilities, nowadays even the more demanding dynamic assignment models are practically usable. Another distinction between models can be based on whether the models are more of an analytical or simulation-related nature. Although the difference between analytical and simulation models is not always clear-cut, analytical models can be defined as those that use direct mathematical computations to determine system states, whereas simulation models use more various rules (mostly in the form of mathematical equations) for movement of vehicles in a system (individually or platoons) (see Akcelik and Associates, 2005). A final important categorization of assignment models can be based on whether they are deterministic or stochastic (TRB, 1994). Stochastic methods allow for uncertainty in the estimates (e.g. different people do not have the same preferences) by incorporating random variables (Ortúzar and Willumsen, 2001). Deterministic assignment, on the other hand, does not take randomness into account, but looks at and chooses the best single/point estimate (e.g. route).

The question as to which traffic assignment model is applicable to this geographical accessibility study depends on several factors. First of all, both model packages (i.e. Flowmap and the assignment model) must be able to use the same study area. Secondly, it would be preferable to choose a traffic assignment model, which is state-of-the-art and can be applied at a regional level. Thirdly, the multidisciplinary characteristic of the MD-PIT project would be enhanced if traffic modelling studies conducted by one research partner[65] could be connected to the geographical accessibility studies. In light of all these aspects, a decision was made to use the analytical dynamic traffic assignment model called INDY. This model is a macroscopic model and therefore can cope with study areas of the preferred geographical scale (for the accessibility analysis). Moreover, the model is state-of-the-art in modelling because it uses a dynamic assignment approach and is capable of distinguishing different user classes (see Versteegt and Bliemer, 2003; Bliemer *et al.*, 2004).

In conclusion, two models are used for the sensitivity of geographical accessibility change studying chapter 4. A traffic assignment model is applied to model behavioural changes due to road pricing measures. The output, in the form of network link travel times before and after implementation of a pricing measure, is then used as input for the Flowmap. This GIS-extension subsequently computes geographical accessibility indicators and the sensitivity of the outcomes. The overall total analysis is aimed at answering research question 2 (see chapter 4).

3.5.2 - Discrete choice estimation

Choice data derived from stated choice experiments such as described in the sections 3.4.2 and 3.4.3 can be analysed through discrete choice models. By far the easiest and most widely used discrete choice model is multinomial logit (MNL). This model can be derived from the random utility theory. Utility theory can be used as a basis for explaining dominance judgements among offered alternatives, such as in stated choice experiments. A decision-maker (i.e. the respondent) chooses the preferred option from a set of alternatives on the basis of the attributes and (level) values that characterize that alternative. This preference or utility for a certain alternative can be expressed in a mathematical form: the utility function. Assume a decision-maker labelled n, faces j alternatives. Then, the utility that the decision-maker obtains from alternative j is decomposed into (see Train, 2003): a part labelled V_{nj}, the systematic component of utility, which is known by the researcher up to some parameters; and an unknown part ε_{nj}, the random or error component, that is treated as random by the researcher (see equation 3.1).

$$U_{nj} = V_{nj} + \varepsilon_{nj} \forall j \quad [3.1]$$

[66]

The random part is not one fixed term, but follows a distribution because the values of the unobserved factors vary among people. Train (2003) mentions three ways to think about this distribution:

- The distribution of ε_{nj} can be seen as the unobserved portion of utility within the population of people facing the same systematic utility (V_{nj});
- The distribution can be considered as representing the researcher's subjective probability that the decision-maker's unobserved utility will take a given distribution;
- The distribution can represent the effect of factors that are quixotic (i.e. unpredictable) to the decision-maker himself (e.g. aspects of bounded rationality).

65 Van Amelsfort, D., who works for Delft University of Technology and Goudappel Coffeng BV.

66 The symbol ∀ stands for 'for all'.

The key assumption in the case of the mulinomial logit model is that the error components, ε_{nj}, are independent of each other. This means that the unobserved portion of utility for an alternative within a choice set is independent of the unobserved components of utility for all other alternatives. Furthermore, as described above, the random part may vary per respondent and therefore follows a distribution. For mulinomial logit models the random part is independently (i.e. independent errors for different alternatives), identically distributed (i.e. the same statistical distribution) (IID) extreme value (Louvière *et al.*, 2000; Train, 2003). Using the extreme value distribution for the errors is nearly the same as assuming that the errors are independently normal except for the slightly fatter tails of the extreme value distribution.

An important characteristic of utility theory is that the absolute level of utility is irrelevant to both the decision-maker's behaviour and the researcher's model. This has implications for the identification and specification of choice models (Train, 2003). Only parameters can be estimated that capture differences across alternatives. In addition, just as adding a constant to the utility of all alternatives, multiplying each alternative's utility by a constant does not change the decision-maker's choice either (see Train, 2003). Starting from the utility function and its characteristics, the mathematical expression of the probability that the decision-maker n chooses alternative i is (see Train, 2003):

$$P_{ni} = Probability(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj} \forall j \neq i) \qquad [3.2]$$

The decision-maker chooses alternative i if the utility (the observed plus random part) of alternative i is larger than the utility of alternative j. In other words this simply means that the decision-maker chooses the alternative with the highest utility. This is a deterministic choice. However the height of the utility is probabilistic. Bringing V_{nj} to the other side in equation 3.2, using the cumulative distribution for ε_{nj} and using algebraic manipulation leads to the following closed form expression (see Train for this derivation):

$$P_{ni} = \frac{e^{V_{ni}}}{\sum_j e^{V_{nj}}} \qquad [3.3]$$

Equation 3.3 implies that the probability that a decision-maker (e.g. the respondent) chooses alternative i from a choice set consisting of j alternatives is equal to the exponential function of the observed (or systematic) part of utility derived from alternative i divided by the sum of 'exponential' utilities of all alternatives j within the choice set. Equation 3.3 is called the multinomial logit model (MNL)[67]. Representative utility is usually specified to be linear in parameters: $V_{nj}(\beta) = \beta' x_{nj}$, where x_{nj} is a vector of observed variables relating to alternative j. With this specification, equation 3.3 can be finally rewritten as:

$$P_{ni} = \frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}} \qquad [3.4]$$

67 The term multinomial logit model is used when the probabilities of choosing an alternative among a set of more than two alternatives are studied. However, if only two alternatives occur in a choice set, it is better to speak of a binomial logit model. Multinomial logit is thus reserved for cases with more than two choices.

The choice probability P_{ni} follows a sigmoid shape and lies between 0 and 1. The curve asymptotically approaches zero and one but never actually reaches either value. The shape of the probability function implies that an increase in representative utility has the greatest effect on the probability of (an alternative) being chosen when the probability is close to 0.5. At this point, the function is at its steepest. Another property of logit models is that the sum of the probabilities for all alternatives is 1.

To estimate model coefficients (i.e. β's) on the basis of a logit model, a maximum likelihood estimation has to be made. These estimates are derived for each parameter in the model by computing the first derivative of the likelihood function and equalling this derivative to zero (see, for example, Louvière *et al.*, 2000). The maximum likelihood estimates of β are those that make the predicted average of each explanatory variable equal to the observed average in the sample. The likelihood function can further be used for computing a goodness-of-fit statistic called the likelihood ratio index (see Louvière *et al.*, 2000; Train, 2003). This ratio is defined as:

$$\rho^2 = 1 - \frac{LL(\hat{\beta})}{LL(0)} \qquad [3.5]$$

where is $L(\hat{\beta})$ the value of the log-likelihood function at the estimated parameters and LL(0) is its value when all the parameters are set equal to zero. The statistic measures how well the model performs compared to when all parameters are set to zero (i.e. equal to no parameters in the model). The ρ^2-value by definition always lies between 0 and 1. A value close to 0 indicates a bad prediction. whereas values approaching 1 indicate that the estimated parameters predict the observed choices by the decision-makers very well. The ρ^2 is used as a type of pseudo-R^2 to measure the goodness-of-fit of the MNL model (Louvière *et al.*, 2000). However, despite both statistics having the same range, the interpretation is not at all similar. R^2 indicates the percentage of the variation in the dependent variable that is 'explained' by the estimated model (Train, 2003). But the likelihood ratio does not have a good interpretable meaning for the value between zero and one. It only represents the percentage increase in the log-likelihood function above the value taken at zero parameters (Train, 2003). Although it is usually valid to say that a model with a higher ρ^2 performs better, this statement is only valid when the model is estimated on an identical sample with the same alternatives. If this is not the case, the likelihood ratio cannot be used to draw conclusions about the model fit (see Train, 2003). Moreover, values for ρ^2 are not as high as may be expected from good model fits on the basis of the R^2. Louvière *et al.* (2000) state that values of ρ^2 between 0.2 and 0.4 are considered to be indicative of extremely good model fits. The ρ^2-test can be improved by adjusting it for degrees of freedom that is useful when different models have to be compared. This value is termed the corrected ρ^2 or $\bar{\rho}^2$. The larger the sample of choices the smaller the difference is between the corrected and uncorrected ρ^2.

As described before, error terms are not correlated over and between alternatives in the case of the standard logit model. This IID assumption is central to using the MNL model. The assumption of independently and identically distributed error terms (IID) causes the multinomial logit model to have a closed form, which makes the MNL model easy to handle. In addition, the IID assumption also causes the MNL model to exhibit the property of independence of irrelevant alternatives (IIA). This means that the ratio of logit probabilities does not depend on adding any alternatives. For example: suppose a decision-maker can choose between two essentially the same cars but with different colours (red and yellow) to be used for commuting. Assume also that the representative utility of the two cars is the same. This leads to a probability for each car of being chosen of $P_{red} = P_{yellow} = 1/2$ (and a ratio of 1). If now a blue car is introduced with the same characteristics, the IIA assumption assumes that this introduction will not change the ratio between sold red and yellow cars (i.e. $1/2$). Because the blue car is the same as the other cars, it may be expected that it will achieve the same market share as both other cars. But due to the constraint of probabilities over all alternatives summing to 1, the probability of choosing a red or yellow car will decrease to $33^1/_3$ percent, leaving the ratio-value of 1 untouched. This seems quite realistic. However, the IIA property may be inappropriate in other situations, such as the famous red-bus-blue-bus problem (Ortúzar and Willumsen, 2001; Train, 2003). A traveller now has the choice to go to work by car or by taking a blue bus. For simplicity again assume that the representative utility of the two modes are the same, such that their choice probabilities are $P_{car} = P_{bluebus} = 1/2$ (and a ratio of 1). Now suppose the manager of the bus company decides to paint half the buses red. Then the probability of choosing the red bus will be the same as the probability of choosing the blue one (i.e. a ratio of 1). Due to the IIA assumption, the ratio between car and the blue bus remains the same. This can only be reached when the probability of choosing a car is equal to choosing the red or blue bus (e.g. $1/3$). However, this outcome is quite unrealistic. The expectation in reality would be that the blue bus competes with the red bus and that the overall probability of the car being chosen remains the same. Thus, the expectation is that $P_{car}=1/2$ and $P_{redbus} = P_{bluebus} = 1/4$. Although this example is not likely to occur in reality, it indicates that the MNL model does not cope correctly with the introduction of new alternatives that may change ratios.

In addition to the quite unlikely characteristic of independence of irrelevant alternatives (IIA), the assumption of independently and identically distributed error terms (IID) for MNL models has several other shortcomings. First of all, MNL models can cope with tastes that vary systematically in the population in relation to observed variables, but cannot account for random taste variation[68] (Train, 2003). This means that MNL models can account for variation in responses due to, for example, measured socio-economic and demographic characteristics (systematic variation). However, people with the same observed (socio-economic and demographic) characteristics may still respond in a different way due to unmeasured or unobserved characteristics and perceptions or attitudes (random variation). The unobserved heterogeneity effects lead (indirectly) to non-IID error structures across alternatives at each choice occasion, such that the IIA property does not hold at any choice occasion (Bhat and Castelar, 2002). Secondly, the IID assumption also implies that all observations are independent. In most stated choice experiments, from an efficiency point of view, a respondent is presented different choice sets. Therefore, socio-economic descriptors do not vary across choice situations for a given sampled individual (Hensher and Greene, 2003). In addition, the sequencing of offered choice situations may result in mixtures of learning and inertia effects, and if choice sequences are too long, they may lead to fatigue effects (see Adamowicz, 1998; Hensher and Greene, 2003). All these effects violate the independence of observations and thus the IID-assumption. But because the MNL model entails the IID-assumption, using a MNL approach cannot assess the extent to which these effects influence the results. Thirdly, state-dependence and heterogeneity in state-dependence effects may lead to a violation of the IID-characteristics, which cannot be tested by applying a MNL model. The

68 Taste variation is called 'preference heterogeneity' by Hensher and Greene (2003).

term state-dependence thereby reflects the effect of actual past choices on current choices (Bhat and Castelar, 2002). And finally in the fourth place, MNL models cannot account for correlation between attributes within and over alternatives[69] (Hensher and Greene, 2003). Thus, MNL models cannot cope with correlation of the unobserved (random) portion of utility.

According to Train (2003), if this correlation between and over alternatives is expected the researcher has three options: the first one is to re-specify the representative utility so that the source of correlation is captured explicitly and thus remaining errors are independent; however, it is not possible to include unobserved characteristics. Secondly, the researcher can use the multinomial logit model as an approximation; logit model results seem to be rather robust, especially when estimating averages (see also Louvière *et al.*, 2000; Train, 2003). A third option is to use a different model that allows for correlated errors.

Different types of models exist that can cope with correlated errors, for example the generalized-extreme-value models (GEV), which are based on a generalization of the extreme-value distribution. The generalization can take many forms, but the common element is that it allows correlation in observed factors over alternatives and collapses to the (multinomial) logit model when this correlation is zero (Train, 2003). A relatively well-known and regularly applied type of GEV-model is the nested logit model (see Louvière *et al.*, 2000; Train, 2003). Nested logit models place alternatives in different 'nests'. Subsequently, alternatives within a nest are 'allowed' to correlate. Between nests, the correlation is zero. More complex forms essentially allow for any form of correlation (Train, 2003). As is the case with MNL-models, GEV-models have a closed form (see Louvière *et al.*, 2000).

Probit models are another type of models. Within probit models the unobserved factors are distributed statistically 'normal'. According to Train, the main advantage of the probit model is its flexibility in handling correlations over alternatives and time. A disadvantage is that only a normal distribution can be applied for the error/random component, while the preference for some attributes may well be distributed not normally, such as travel time or travel costs[70]. The probit model has no closed form, which implies that a simulation approach (with a certain number of 'random draws') is needed to estimate parameter values[71].

A third type of model that nowadays is used more and more, is the mixed logit model (or random parameters model). Mixed logit obviates three limitations of the multinomial logit model by allowing for random taste variation, unrestricted substitution patterns and correlation in unobserved factors over time (Train, 2003). Unlike the probit model, non-normal distributions can be used as well. This makes mixed logit models more flexible. As with the probit model, the mixed logit model formulation is not closed, which means that a simulation approach is needed to evaluate probabilities. The great advantage of mixed logit models is that any random utility model (e.g. standard logit, nested logit, probit etcetera) can be approximated to any degree of

69 Bhat and Castelar (2003) use the term inter-alternative error structure.

70 In the case of travel time and costs which are needed to derive values of time, lognormal or triangular preference distributions seem to be more suited (see Hensher and Greene, 2003).

71 For an elaborate explanation of closed and non-closed model forms, see Louvière *et al.* (2000) and Train (2003).

accuracy by a mixed logit with appropriate choice of variables and a mixing distribution (Train, 2003; but also see McFadden and Train, 2000 or Hensher and Greene, 2003).

The mixed logit model can be written in the following general form (see Train, 2003):

$$P_{ni} = \int \left(\frac{e^{V_{ni}(\beta)}}{\sum_j e^{V_{nj}(\beta)}} \right) f(\beta) d\beta \qquad [3.6]$$

The first part in equation 3.6 resembles the logit probability evaluated at parameters β, with V_{ni} representing the systematic utility of decision-maker *n* for alternative *i*. Furthermore, *f(*β*)* is a (continuous) density function (with a mean *b* and covariance *W*). The mixed logit model consists of two stochastic terms. One component is the well-known ε_{nj} error component, which is the same as in the standard logit specification and is IID extreme value type I. In addition, a second stochastic term is introduced which can capture variance and correlation in unobserved factors and thus can relieve the strict IID assumption. This can be done in two different ways: the random parameter specification and the error components approach (see Hensher and Greene, 2003; Train, 2003). In the random specification approach, a distribution is introduced around (certain) variables within the model specification to capture taste variation of persons. Thus, the aim of including a distribution in this case is to be able to include taste variations among decision-makers. The error components approach, on the other hand, is primarily concerned with enabling correlations between error components in the model estimations. Error components and random coefficient specifications are formally equivalent (Train, 2003). The only difference is caused by the way a researcher thinks about the model. For example, in the case of looking for random variables the approach may be to test all variables in a model on randomness whereas in the case of looking for errors the aim may be on specifying certain variables that can induce correlation over alternatives (see Train, 2003).

The researcher is free in choosing the type of distribution that is applied for every random variable. In most applications normal and lognormal distributions are used (Train, 2003). The lognormal distribution is often used when the coefficient is known to have a certain sign. For example, costs are almost always valued negatively. Next to (log)normal distributions, uniform and triangular distributions are sometimes applied. The advantage of the latter types of distributions is their ability to bound the distributions, thereby avoiding problems of very large coefficients that can occur when estimating coefficients at the tails of the distribution. The probabilities are approximated through simulation by drawing a value of β from the chosen distribution *f(*β*)*, to calculate the logit formula with this drawn β and repeat these two steps for every simulation run that is conducted. Then, results are averaged into a simulated probability (see Train, 2003):

$$\breve{P}_{ni} = \frac{1}{R} \sum_{r=1}^{R} L_{ni}(\beta^r) \qquad [3.7]$$

Within equation 3.7, *R* resembles the number of draws in the simulation and $\breve{P}_{ni}$ is the unbiased estimator of the probability P_{ni}. Its variance decreases as *R* increases and the simulated probability sums to 1 over alternatives. Finally, because the estimated probability is achieved by simulation the maximum likelihood estimator is also simulated (MSLE).

Since mixed logit models need a simulation approach an important consideration is the number of draws needed for stable results. According to Hensher and Greene (2003), the number of draws required for a stable set of parameter estimates varies enormously and depends on the complexity of the model specification in terms of the number of random parameters that have to be estimated. The best test for stability is to estimate parameters over a range of draws. In most cases no more than 1000 draws are used. The reason for keeping the number of draws as small as possible is the needed computation time, which can be hours for simulating models with many runs. For that reason Halton draws are often applied, which take 'intelligent' draws from the uniform distribution, rather than random ones (see Greene, 2002; Hensher and Greene, 2003). This Halton procedure appears to reduce the number of draws considerably and thus the time needed for estimation (by a factor 90 percent or more) (Greene, 2002). This implies, for example, that 100 Halton draws can produce the same or a lower simulated variance than 1000 random draws. Therefore, Halton draws are preferred above the totally random approach.

In conclusion, different types of logit models can be used to analyse stated choice data. The simplest and most easily applicable form is the multinomial logit model. This model suffices in many applications. However, models can also be used that relieve some of the strict assumptions of the multinomial logit models (i.e. the IID and IIA assumption). With respect to those models the mixed logit models are the state-of-the-art. An important feature of these models is their ability to take account of preference heterogeneity in unobserved factors. In contrast to the multinomial logit model, mixed logit outcomes can only be obtained by simulation. With respect to the research described in this thesis, logit models (multinomial as well as mixed) are used for two things. First of all, logit models are estimated on the basis of data described in section 3.4.2 to derive some insight into realistic values of time for application in the accessibility sensitivity study in chapter 4. Secondly, multinomial and mixed logit models are estimated by means of the stated choice experiment data described in section 3.4.3. These logit estimations give insight into how (types of) respondents trade-off location and house characteristics, travel time and travel cost characteristics when choosing a residential location. These outcomes are used to answer part of research question 3. The mixed logit models are estimated with the primary aim of taking random taste variation into account. Moreover, these type models are used to account for the fact (i.e. correlation) that a same individual within the stated choice experiments was offered several different scenarios[72]. This can be seen as a sort of panel data effect. The statistical package that is used for estimating the models is LIMDEP (see Greene, 2002).

3.5.3 - Ordered regression estimation

The linear regression model estimated via the method of ordinary least squares (OLS) is suitable to use if the dependent variable within the analysis is continuous (i.e. interval or ratio scale). However, several behavioural changes within the questionnaire studies were studied by using response scales on an ordinal or categorical scale. An example of a rating scale used within the questionnaire is as follows:

1. highly unlikely
2. unlikely
3. quite unlikely

72 This 'repeated choice problem' was accounted for by using the standard 'Pds' option available within the LIMDEP software (see Greene, 2002).

4. not unlikely, not likely
5. quite likely
6. likely
7. extremely likely

In analysing data collected at a categorical level, the linear regression model is no longer suitable. In such cases a logit model could be specified with each potential response as an alternative (Train, 2003). However, this would be inconsistent with the IID assumption (see section 3.5.2) because with ordered alternatives, one alternative is more similar to those close to it and less similar to those further away (Train, 2003). To account for this IID-violation, probit or mixed logit models could be used. Train (2003) states that, although such methods may give good results, applying them would not actually fit the structure of the data. An example can clarify this. Assume a respondent is asked to indicate on the 7-point rating scale mentioned above the likeliness that he or she is going to change his or her residential location due to a certain pricing measure. Then, using a discrete choice approach would assume that there are 7 utilities, one for each potential response and that the respondent chooses the number (1 to 7), which has the largest utility. According to Train (2003) a more natural representation of the decision process is to assume that the respondent has a utility on the object of the question (i.e. the likeliness to move due to the pricing measure) and answers the question on the basis of how big his or her (dis)utility is. The most suitable method to analyse this kind of data is the method of ordered regression/choice analysis. The ordered choice model is based on the following specification (Greene, 2002):

$$y_i^* = \beta' x_i + \varepsilon_i \qquad [3.8]$$

where y_i (the actual response) is the observed counterpart of y_i^* for individual i; x_i is the set of explanatory variables and ε_i is the random error term. Thus, the person chooses a response on the basis of the level of his or her utility. The decision can be presented as follows:

$$\begin{aligned} y_i &= 0 \text{ if } y_i^* \le \mu_0, \\ &= 1 \text{ if } \mu_0 < y_i^* \le \mu_1, \\ &= 2 \text{ if } \mu_1 < y_i^* \le \mu_2, \\ &\dots \\ &= J \text{ if } y_i^* > \mu_{J-1} \end{aligned} \qquad [3.9]$$

where J indicates the number of response classes, and μ*'s* represent the cut-off points for the different classes. Probabilities that a certain class is chosen enter the log-likelihood function and maximization of the likelihood function finally provides estimates of the parameters. As a goodness-of-fit measure the chi-square value can be used.

Different types of ordered regression models can be applied, depending on the link functions (see Bender and Benner, 2000; Chen and Hughes, 2004) used for ε_i. Greene (2002) distinguishes four functional types: the ordered logit model, the ordered probit model, and finally the ordered extreme value and ordered Gompertz models. The ordered logit model uses the logistic distribution for the choices made. The probit model, on the other hand, is obtained under the assumption that the random term (ε) is distributed standard normal instead of logistic (Train, 2003). The complementary extreme value or Weibull function and the Gompertz function are based on asymmetric distributions with skews to the right and left respectively (Greene, 2002). These latter types of distributions may be more suitable when categorical data are not evenly distributed among all categories. The most frequently applied distribution types, however, are the first two (i.e. logit and probit). According to Garson (2005) the choice of function (logit or probit) depends to a large extent on one's personal preference. The probit curve is slightly steeper, but differences between using an ordered logit or probit approach are small. Van Dijk and Pellenbarg (1999) also tested both approaches and, in line with Garson's remarks, only found slightly different results.

Sometimes respondents have to answer a certain question at different periods in time or respond to the same kind of question more than once in a questionnaire. A tailored example of the latter case with respect to the questionnaire study in this thesis is when one respondent has to indicate his or her behavioural change intention (e.g. relocation intention) due to several (related) pricing measures in one questionnaire. If the choice is made to estimate one model on a combined 'behavioural change' variable (e.g. relocation responses of a respondent due to different pricing measures) with, for example, price measures being incorporated as an independent variable, then in fact a sort of correlation may occur. People that respond in a certain way to one type of price measure may respond in quite the same way due to another price measure. To 'capture' possible correlations more advanced random parameter ordered choice models[73] (Greene, 2002) can be estimated. These models were developed to estimate ordered choice models on data including repeated choices (e.g. panel data; or cross-section data including repeated choices being made by one respondent). The random parameter model can be formulated in a general form as (Greene, 2002):

$$f(y_{it} \mid x_{it}, z_i) = g(y_{it}, x_{it}, z_i, \alpha_i) \qquad [3.10]$$

Where *g(.)* is the probability density for the observed response of the *i*th individual at time t, y_{it} is the observed response at time t given different time variant (x_{it}) and invariant (z_i) characteristics. α_i is a person specific parameter vector that varies randomly across individuals, with mean α and covariance Ω. This model formulation does not only provide the possibility to study repeated choice related correlations but also may be used when the researcher wants to include parameters into the model that vary randomly in the population.

In conclusion, within this thesis ordered regression models are used to analyse data from questions that were answered on a 7-point categorical scale. For example, all 'relocation'-related questions are measured on such a categorical scale (research question 3). Moreover, almost all firm-related behavioural questions were measured on a 7-point categorical scale. Thus, to answer research questions 3 (partly) and 4, ordered regression models are needed. For estimating ordered regression models, the statistical estimation package LIMDEP (Greene, 2002) is used. Within LIMDEP the ordered probit model is the default specification. Because of the small differences in results expected on the basis of the literature (for example Van Dijk and Pellenbarg, 1999) the probit model is used as a default model for estimating models on categorical data within this thesis. At some places in chapter 6 and 7 more advanced random parameter

73 Train (2003) calls these models mixed ordered logit models.

ordered probit models are used to take account of possible correlation effects and to include preference heterogeneity (see section 6.3.4.1 and 7.3.3.1 for specific motivations).

3.5.4 - Poisson and Tobit estimation

A part of the second household questionnaire described in section 3.4.4, focused on obtaining insight into the trip-related behaviour changes of households due to different pricing measures. In short, respondents were first asked to indicate whether or not they would change their current behaviour. Those who responded to be intended to do so were asked in how many cases (on a four week basis) they would change their current car trips (see section 3.4.4 for a more elaborate overview). The data (i.e. the number of car trip changes) can be regarded as count data. For estimating models with explanatory variables for count data, Poisson regression is a suitable technique (Greene, 2002). A characteristic following from the Poisson distribution is that the mean is equal to the variance. Any factor that affects one will also affect the other. This means that the usual assumption of homoscedasticity would not be appropriate for Poisson data. Focusing on the model description of Poisson regression, suppose a sample of n (i.e. number of respondents) observations $y_1, y_2, \ldots, y_n$ (e.g. number of car trips changed for each respondent) which can be treated as realizations of independent Poisson random variables and suppose that the mean μ_i depends on a vector of explanatory variables x_i (Rodríguez, 2001). A simple linear model formulation may look as follows:

$$\mu_i = \alpha + \beta x_i' \qquad [3.11]$$

With α being a constant and β representing estimated coefficients. The model formulation in 3.11 has the disadvantage that the linear part on the right hand side in principle can take on any value (also negative) whereas the mean value μ_i, which represents the expected count, has to be non-negative. A solution is to model the logarithm of the mean using a linear model (Rodríguez, 2001). If logs are taken and it is assumed that the transformed mean follows a linear model, 3.11 can be rewritten to:

$$\log(\mu_i) = \alpha + \beta x_i' \qquad [3.12]$$

In equation 3.12 an estimated coefficient β represents the expected change in the log of the mean per unit change in the predictor x. If μ_i are independent observations with corresponding values of x_i of the predictor variable, then α and β can be estimated by maximum likelihood if the number of distinct x values is at least 2. The maximum-likelihood estimates lack a closed-form expression and must be found by numerical methods.

Although respondents only had to indicate how many current car trips they intended to adjust due to a pricing measure, this number is dependent on how many car trips the respondent currently makes. As described in section 3.4.4 respondents could not adjust more car trips than they currently undertake. Thus, because there is a link between current and future (adjusted) behaviour, the decision was made to examine differences in explanatory factors for changing behaviour due to pricing also on the basis of a so-called ‘effectiveness ratio’. This ratio is equal to the number of car trips changed within a four week period divided by the total number of trips undertaken in a four week period[74]. The resulting dependent variable is then a ratio-variable, which implies that Poisson regression is not a correct technique to be used. In the case of a dependent variable measured on a ratio-scale, linear regression analysis could in principle be used to estimate explanatory models. However, many respondents indicated that they would not change their car trip behaviour. As a result, the sample is actually censored. In general, a censored sample means that the dependent variable y is known exactly only if some criterion defined in terms of the value of y is met, such as $y>c$ (see Breen, 1996). In this case, respondents who do not change their trip behaviour can be seen as having a zero value for y. Thus, y is only observed exactly for $y>0$. A further characteristic of censored samples is that explanatory variables (x) are observed for the entire sample, regardless of whether y is known exactly (Breen, 1996), which also holds for the sample described in section 3.4.4.

When there is a censored sample and a continuous dependent variable, linear regression analyses are not so useful anymore. Linear regression analyses use ordinary least squares (OLS) to regress the dependent variable on the explanatory variables. The usage of OLS in analysing censored data leads to biased parameter coefficients (see for an explanation Breen, 1996) even when linear regression analysis are only used for the sub sample of people that indicated to change their trip behaviour. Therefore other statistical techniques have been developed for analysing censored data. The simplest model for analysing this type of data is the so-called Tobit model developed originally by Tobin (1958). This model can be written in terms of the underlying or latent variable as (see Breen, 1996; Greene 2002):

$$y_i^* = \beta' x_i + \varepsilon_i \qquad [3.13]$$

in which y_i^* stands for the underlying latent variable of household i, of which y is the realized observation. It is assumed that ε_i's are independent and normally distributed errors with a zero mean and constant variance, σ^2 (Breen, 1996). Finally, x indicates the explanatory variables, with β as (to be) estimated coefficients. However, the latent variable is only observed for a certain sub-sample (for example $c>0$). More formally, the relationship between the observed and latent variables can be written as (see Breen, 1996; Greene 2002):

$$\begin{aligned} y_i &= y_i^* \quad \text{if} \quad y_i^* > c, \\ y_i &= c \quad\ \ \text{if} \quad y_i^* \leq c \end{aligned} \qquad [3.14]$$

where c is the threshold for censoring (c=0 in the household questionnaire described in section 3.4.4). For estimation of the β-coefficients maximum likelihood techniques are used. These coefficients can be interpreted in the same way as the β-coefficients from an OLS. Nevertheless, an important consideration of using maximum likelihood estimators is that they are asymptotically efficient. This means that they have the property of efficiency only when the sample size is large (enough).

The Tobit model described by the combination of equation 3.13 and 3.14 assumes that the same set of variables (x), with the same coefficients, determines both the 'choice' to change behaviour as well as the realized or latent variable. Yet, if the expectation is that the variables influencing

74 Because of this ratio, Poisson regression can no longer be used.

the probability of change are (partly) different from those that influence the size of the actual change, other types of models can be applied. The best known models for these situations are the Heckman two-step and the maximum likelihood method, the latter one of which is generally preferred (for reasons see Breen, 1996). However, in the specific situation of trip behaviour change due to road pricing, there is no clear expectation (ex ante) that explanatory variables will differ for the two stages (i.e. choice and rate of change). Therefore, analysis will be limited to Tobit estimation.

In conclusion, Poisson regression is a suitable statistical technique to estimate explanatory models on the basis of count data, as is the case with the car trip change data in questionnaire 2 (see section 3.4.4). If the intended car trip change is related to the current number of trips by dividing trips changed by current car trips, the dependent variable in fact becomes a ratio variable. Linear regression models can be used to estimate explanatory models on these kinds of data. However, since the data sample is censored, Tobit analyses may be more suitable to use. Within this thesis Poisson and Tobit analyses are applied to gain insight into explanatory variables for trip change behaviour due to road pricing. The analyses are only carried out for data described in section 3.4.4. Analyses on data of changes in shopping trips (i.e. see section 3.4.5) are limited to descriptive techniques because of the relatively smaller sample size. The Poisson and Tobit results are reported in chapter 5 and are used to answer (a part of) research question 3.

3.5.5 - Overview of links between analytical techniques and research questions

A summarizing overview of which analytical technique(s) is/are primarily used to answer the various research questions is provided in Table 3.9. As indicated earlier, research question 1 was answered in chapter 2. Research question 2, which is concerned with studying the sensitivity of accessibility outcomes, is answered by using a simulation approach. Value of time ranges that are applied in the sensitivity analysis are explored by estimating logit models on stated choice data from household questionnaire 1A and 1B (see also Table 3.8). For the actual simulation approach, two types of models are used: a traffic assignment model (INDY), which calculates link travel times for situations before and after implementation of road pricing; these link travel times are used as input in a GIS-extension package (Flowmap) that is able to compute geographical accessibility but cannot simulate traffic behavioural changes (which influence travel time). Thus, the two models together lead to synergy effects.

To answer research question 3 different statistical approaches are used. (Multinomial and mixed) logit models are used to gain insight into trade-offs households make between travel time, costs and location/house-related characteristics when choosing a residential location. Furthermore, (random) ordered probit analyses are used for the analysis of explanatory variables for the relocation probability due to pricing measures. T-tests, Anova and Poisson and Tobit analyses are applied to learn more about explanatory factors for changing the car trip behaviour due to pricing measures. Finally, research question 4 is answered by applying (random) ordered probit, factor and cluster analyses.

3.6 - Concluding overview of research methods and design

Table 3.10 gives a total summarizing overview of the research methods, the empirical data and the analytical techniques used to derive an answer to the research questions. The Table is a worked-

Table 3.9: primary analysis techniques to be used to answer the research questions

Research question	Short clarification of research question	Analysis technique
1	Applicability accessibility measures for modelling road pricing (RP) accessibility effects	Not applicable *The first research question was answered in chapter 2 primarily on basis of literature*
2	Sensitivity accessibility changes due to RP and implications	Simulation packages INDY + Flowmap
3	Behavioural changes households due to pricing	T-tests, ANOVA-analysis,* Poisson and Tobit regression (for analyzing trip change behaviour); ordered probit and random parameter ordered probit analyses (for relocation chances); multinomial and mixed logit models (for location trade-offs)
4	Accessibility and behavioural changes firms	Ordered probit, random parameter ordered probit analyses (and cluster and factor analysis*)

* These analysis techniques are not explained in this chapter, because they are regarded to be conventional and well-known analysis techniques. In the specific chapter sections in which these techniques are utilized, their use is motivated and explained.

Table 3.10: links between research questions, methods, empirical data and analysis techniques

Research question* (section 1.2)	Research method (section 1.3)	Empirical data (section 1.4)	Analysis technique (section 1.5)	Chapter reference
1. Applicability accessibility measures for modelling road pricing (RP) accessibility effects.	Office-desk research (literature review)	Not needed	Not needed	Chapter 2
2. Sensitivity accessibility changes due to RP and implications.	Input data from SP data + simulation approach	• HH 1A, 1B (stated choice) • Study area 'Eindhoven'	• Logit models (value of time range exploration) • Models: Flowmap and INDY	Chapter 4
3. Behavioural changes households due to pricing	SP data	• HH 1B (stated choice) • HH 2 (behavioural changes households)	• Logit models • T-tests, ANOVA analysis, Poisson and Tobit regression (trip changes)	• Chapter 6 • Chapter 5
			• (Random) ordered probit analysis (relocation)	• Chapter 6
		• HH 3 (shopping trip changes households)	• Frequency analysis, T-tests	• Chapter 5
4. Accessibility and behavioural changes firms	SP data	Firm questionnaire (FQ)	• (Random) ordered probit, cluster and factor analysis	Chapter 7

* For the complete formulation of the research questions see section 3.2 or chapter 1.

out version of figure 3.1 presented in section 3.1. The columns labelled 'empirical data' and 'analysis technique' are linked by means of arrows to indicate the relation between the type of data and the analytical techniques. Clarifying information regarding the motivation for chosen research methods and analytical techniques as well as a description of the empirical data can be found in the specific sections of this chapter to which the Table refers. Finally, the last column outlines which question is answered in which chapter (see also section 1.5).

In this chapter we discussed and clarified the research methods and design. In the next chapter we present our first 'results'. Chapter 4 focuses on the sensitivity of computed accessibility outcomes to all kinds of simulation input characteristics. In doing so, the chapter aims at deriving implications with regard to computing accessibility effects due to road pricing in general, thereby providing an answer to research question 2.

4 - Sensitivity of geographical accessibility measures under road pricing conditions

4.1 - Introduction

Geographical accessibility measures provide an opportunity to gain a quick insight into the effectiveness of (traffic) policy measures such as road pricing. In addition, the accessibility outcomes may help further tailor a (planned) road pricing measure at relatively low monetary costs. Of course, geographical accessibility is not the only evaluation tool that can be used to assess road pricing effects. Economists in general use economic welfare analyses. As we described in section 1.2, economic analyses are particularly suitable to determine average welfare effects of road pricing measures. However, such analyses do not provide insight into the influence of road pricing on the (actual) geographical accessibility of different groups of people living and conducting activities at different locations. Geographical accessibility indicators make it possible to derive such insights. Thus, geographical accessibility measures are able to show the effects of road pricing measures from a broader perspective: they include a spatial component without having to make concessions regarding the ability to incorporate (monetarized) travel time changes due to road pricing measures. Economic welfare analyses remain useful in themselves, but also, for example, in combination with geographical accessibility analyses, as described in section 2.5.3.4 (i.e. using the rule of half as a tool to estimate the aggregate welfare loss for the group of people who change their behaviour due to road pricing).

Chapter 2, section 2.5.2, described that, in essence, contour and potential accessibility measures seem to be the most useful measures to use for assessing accessibility effects due to road pricing measures. In addition section 2.5.3 formulated some refinements or aspects that have to be taken into account when one wants to gain a realistic insight into accessibility effects due to road pricing measures. First of all, it is important to distinguish between several types or groups of people because accessibility changes due to road pricing are unlikely to be the same for everyone. This variation can be (partly) incorporated by differentiating the value of time[75] (VOT) towards influencing group characteristics. Moreover, behavioural changes should be taken into account. Behavioural changes may lead to travel time gains. As long as travel time gains are higher than (groups of) people have to pay for them on the basis of their VOT, accessibility may increase. Travel time gains alone, however, will only compensate the (extra) road pricing-related costs for specific groups of people with a high VOT; as can be derived from the economic welfare theory,

75 In this chapter we use terms such as 'differentiation or segmentation on the basis of the VOT'. However, strictly speaking this use of the concept 'value of time' is not entirely correct. The VOT is a personal characteristic that can be related to a certain trip. It is an 'endogenous' variable. In the cases of using different values of time for different groups, it is better to speak of segmentation on the basis of personal-related, trip-related and possibly other exogenous characteristics that are connected to (or determine) the value of time. To keep the formulations simple, however, the choice was made to not (generally) use this more 'correct' specification in this thesis.

time gains alone will not be high enough to trade off the extra pricing costs for people with an average VOT. Incorporating all behavioural changes when computing accessibility changes due road pricing is practically (almost) impossible. Therefore, in chapter 2, section 2.5.3.4, we proposed a practical way of computing realistic accessibility effects. The proposed technique is also used in this chapter, in which the sensitivity of accessibility outcomes for varying different characteristics is assessed. The overall *goal* of this chapter is to gain insight into the *sensitivity* of accessibility measure outcomes due to road pricing, and to determine the implications of the sensitivities for modelling geographical accessibility effects due to road pricing. Because this chapter focuses on the sensitivity of outcomes rather than on determining the (realistic) accessibility effects as a result of road pricing, no quantitative indication is provided of the welfare loss of groups of people who change their behaviour due to pricing (by using the rule of half).

Two methodological paths in studying the sensitivity of accessibility outcomes due to road pricing are distinguished. On the one hand, the sensitivity is studied for varying aspects that are particularly important in the case of road pricing: the type of road pricing measure, the price level and the specification of the generalized transport cost function. The sensitivity of accessibility effects for the price measure (and price level en elasticity of trip demand) provides initial insight into which types of measures (and price levels) lead to higher accessibility gains or lower accessibility losses compared to other measures (or price levels). Moreover, the sensitivity analysis assesses the sensitivity of accessibility outcomes under road pricing conditions for the generalized cost function used. From a theoretical point of view, realism of accessibility outcomes may be improved if the cost component of the accessibility measure is detailed and differentiated. This includes, for example, using values of time, differentiated towards important socio-economic or demographic characteristics, to take account of the possible non-constancy of travel time valuations in time (see, for example, Gunn, 2001; Rietveld, 2003) and to incorporate, for example, a value of reliability, a fuel cost and/or a revenue rebate component into the resistance function. A disadvantage of this possible increase in realism is that the modelling process becomes more complex and data requirements increase. Insight into the sensitivity to cost-related aspects may give some indication of the importance for differentiating the generalized transport costs when the aim is to get a realistic insight into the accessibility effects due to road pricing measures. On the other hand, the sensitivity is determined for aspects that influence accessibility outcomes in general (i.e. not only in the case of an accessibility measure based on generalized transport costs). In this chapter the following aspects can be attributed to this second methodological path: (i) the influence of the type of accessibility measure used (ii) the sensitivity to the impedance step chosen in the case of contour measures or the sensitivity to the applied cost sensitivity factor when using a potential accessibility measure and (iii) the sensitivity to the zoning and network detail. The sensitivity to the accessibility measure determines whether or not it is wise to use only one accessibility measure when the aim is to give a realistic insight into accessibility effects of road pricing measures. If the sensitivity of accessibility outcomes for the type of accessibility measure is low, little effort has to be put into selecting an accessibility measure. If the sensitivity is high either a carefully motivated choice in favour of a particular accessibility measure is needed, or the decision should be made to use more than one accessibility measure to obtain a more thorough insight into accessibility effects due to pricing measures. An important methodological issue, not only in this study but in all (non-cost-based) geographical accessibility studies, is which type of resistance parameter should be used (i.e. the choice of the impedance step in the case of a contour measure or the costs sensitivity parameter in the case of a potential measure). If the results are sensitive to the chosen resistance parameter this means that either a carefully motivated decision with respect to the selection of the resistance factor has to be made (although this should always be done), or that more than one resistance parameter has to be used when a good insight into the accessibility effects of road pricing measures has to be gained. A final point of consideration in this chapter is the sensitivity to the level of zoning and network detail. A detailed network and zoning system may be preferable from a realism point of view: the possibility of spatial differentiation of results is higher, but if the sensitivity of accessibility results is low for network and zoning detail, this may also legitimise the choice in favour of less detailed zoning systems when, for example, computation time[76] is an important bottleneck in a study. Following from the above, this chapter tries to answer the following research question:

To what extent are geographical accessibility measure outcomes under road pricing conditions sensitive to varying cost (i.e. type of price measure, price level, specification of generalized transport cost function) and non-cost related aspects (i.e. accessibility measure, resistance parameter and network detail), and what implications for modelling geographical accessibility effects due to road pricing can be derived from these analyses?

Figure 4.1 provides a graphical overview of the sensitivity analyses that are carried out in this chapter. The y-axis and z-axis represent the characteristics of the 'reference situation'. On the x-axis the different aspects in the sensitivity analysis are distinguished. The reference situation consists of two accessibility measures (see the y-axis in figure 4.1) and two price measures (see z-axis). All other sensitivity analyses (see x-axis) are conducted on the basis of the reference situation. The reason for including two accessibility and price measures in the reference situation instead of only one was made because of the importance of the choice of the accessibility and price measure. The choice of the price measure and the type of accessibility measures are considered the most fundamental and influencing choices one has to make in studying accessibility effects as a consequence of road pricing. The y-axis shows that with respect to the type of accessibility measure, the contour and the potential measures are used. These measures were chosen because they meet the suitability criteria described in chapter 2 'best' (see section 2.4.3). The two selected price measures are (see z-axis): (i) a time-differentiated kilometre charge on all roads and (ii) a time-differentiated kilometre charge on roads with a maximum allowed speed of 100 kilometre per hour or higher (e.g. the motorways). The decision to use time-dependent kilometre charges, with a higher charge level during the period with the highest traffic demand, was made because these measures are popular in the Dutch political debate due to their assumed effectiveness to reduce traffic congestion (see Nationaal Platform anders betalen voor mobiliteit over de weg, 2005). A time-differentiated charge aims at reducing traffic congestion by spreading the traffic demand more evenly across the day (or peak period). The first kilometre measure, which charges every road in a network, was selected because it provides a good opportunity to make (some of the) current fixed car taxes in the Netherlands more variable, such as fixed (monthly) payments for using the car and fixed taxes on buying a car. The second kilometre charge is spatially differentiated. Traffic congestion in the Netherlands (and in the study area) particularly occurs on specific links, such as on motorways. Charging these links is interesting from a point of view of reducing traffic congestion. In contrast to the first measure route changes may become a more

76 Computation times (and possibly computer system requirements) increase if the number of zones and network links increase.

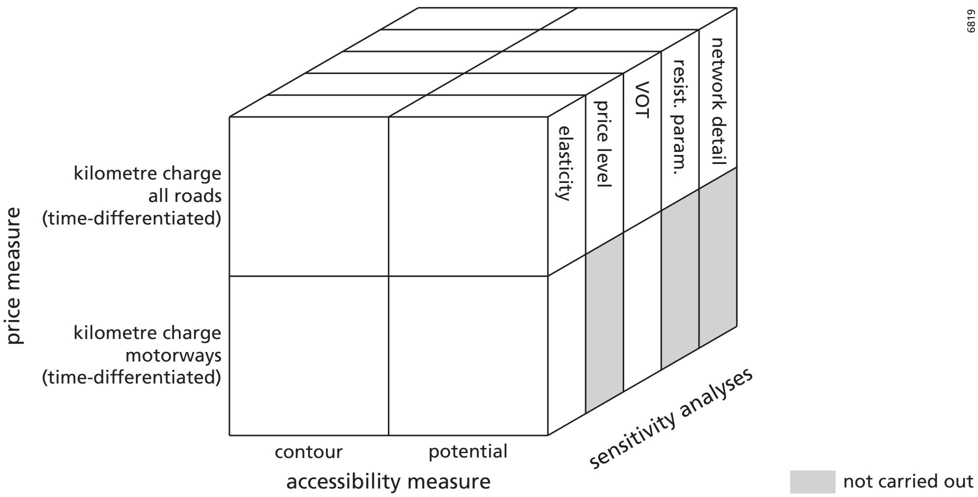


Figure 4.1: overview of the characteristics of the sensitivity study (grey shades indicate: 'not carried out')

influential behavioural change, possibly leading to higher congestion reductions. The reference charge for both measures amounts to 11 eurocents/kilometre during the highest demand period and 3.4 eurocent/kilometre outside that period[77]. The charge of 3.4 eurocents is in line with the charge that is needed to abolish fixed car taxes differentiated according to the weight of the car and a partial reduction of taxes calculated over the price of a new car[78] in the Netherlands, at least when the charge is applied to all roads. Revenues collected by the second (spatially differentiated) charge in fact will not be high enough to actually make fixed costs more variable this way.

The different aspects of the sensitivity analysis are presented on the x-axis, with a distinction between the afore-mentioned two directions in studying the sensitivity (see figure 4.1): (i) the sensitivity to varying aspects that are particularly important in the case of road pricing and (ii) the sensitivity to varying aspects that also influence accessibility when a non-generalized cost based function (e.g. travel time or distance-based) is used. The main emphasis in this chapter is on studying the sensitivity to the 'cost' aspects because of the specific relevance in the case of road pricing. The exact/detailed characteristics of the sensitivity analysis (e.g. the price levels, VOT's used, sensitivity parameters, etc.) are described in section 4.2.2.

The idea is to keep the sensitivity study close to reality. This 'realism' on the one hand is achieved by taking account of important processes which may occur due to road pricing: i.e. changes in travel behaviour due to a pricing measure, leading to travel time changes. These travel time changes are incorporated into the sensitivity analysis. On the other hand, 'realism' is translated

77 The charge in the highest demand period is almost three times higher. This has to do with making different types of price measures that were shown to respondents in a questionnaire within this research comparable with respect to the financial revenues (see section 4.2.2 for a further explanation).

78 See the report of the commission which was installed to advice the Dutch government regarding implementation of a form of road pricing in the Netherlands (Nationaal platform anders betalen voor mobiliteit, 2005).

into varying parameters/variables in the sensitivity analysis within reasonable limits. This means, for example, that the sensitivity of accessibility outcomes is tested for reasonably realistic price measures and values of time.

Especially because of time restrictions (see the Epilogue for a personal evaluation of working in a multidisciplinary study) not all the sensitivity aspects are varied for both price measures within the sensitivity analysis. The grey shadings in figure 4.1 indicate which analyses we did not carry out. The influence of price level variations on accessibility changes is only studied for the time-differentiated kilometre charge on all roads. Moreover, the sensitivity analysis for the resistance parameter used and the level of zoning and network detail (methodological path 2) was only carried out for the kilometre charge measure on all roads. This also has to do with the fact that the main focus and effort in this chapter is on the sensitivity of accessibility outcomes to cost-related aspects. Also, the analysis on the basis of one kilometre charge is expected to give a good indication anyway of the (spatial) sensitivity of accessibility outcomes for the resistance parameter and network detail. Not shown in figure 4.1 is the conducted sensitivity analysis into the influence of adding a fuel cost or revenue rebate component to the generalized transport cost function. This analysis was carried out for the kilometre charge on all roads (and not for the spatially differentiated charge). Because sensitivity results due to adding a fuel cost component can be estimated fairly well on the basis of theoretical reasoning, determining the sensitivity to adding a fuel cost or revenue rebate component for the spatially differentiated charge separately was not considered particularly useful.

As was stated implicitly before, a simulation approach is used to gain insight into the sensitivity of accessibility changes due to systematically varying (cost) aspects. Several reasons for using a simulation based approach can be mentioned. One reason has to do with the afore-mentioned idea to keep the sensitivity study close to reality. This realism is achieved in part by incorporating the travel time benefits of road pricing into the sensitivity analysis. It is virtually impossible to estimate these travel time gains for large networks without using a traffic simulation model. Moreover, the (complexity of the) different stages that can be distinguished in computing accessibility outcomes under road pricing conditions and the sensitivity associated with each stage in combination with the size of (regional) study/research areas make it virtually impossible to gain insight into the sensitivity of accessibility measure outcomes without using simulation models. A higher price level (for the same type of charge) is likely to lead to a higher reduction of travel times at congested points in a traffic network. However, the question is whether, for example, a charge that is twice as high as a 'reference charge' also leads to doubling travel time gains (i.e. a linear relation). Subsequently, it is rather unclear how changes in travel times affect accessibility. A resistance function of an accessibility measure not only consists of monetarized travel time (gains) but contains other cost components as well (e.g. charge costs) that influence the sensitivity of accessibility outcomes to travel time gains. Additionally, the resistance function of potential measures does not have to be linear (see also section 4.2.2), which may also affect sensitivity. Finally, the sensitivity may depend on the number and spatial position of opportunity locations. Overall, this means that many factors and processes may influence the sensitivity of accessibility outcomes under pricing conditions, making it practically impossible to gain a greater insight into the sensitivities without using simulation models.

The outline of this chapter is as follows. Section 4.2 describes the remaining methodology, including the most important characteristics and values used in the sensitivity analysis. Section 4.3 focuses on describing travel time benefits due to applied road pricing measures and explores the sensitivity of accessibility outcomes when the resistance function is expressed in travel time only. Subsequently, section 4.4 is the 'core section' and studies the sensitivity of accessibility outcomes when a generalized transport cost based resistance function is used. Section 4.5, finally, contains the conclusions, a discussion of the results and recommendations.

4.2 - Methodology and simulation characteristics

This section describes the more specific methodological issues and simulation characteristics regarding the accessibility sensitivity analysis that were not discussed in section 4.1. Section 4.2.1 describes the simulation models that are used in the sensitivity analysis and presents some features of the study/research area. Subsequently, section 4.2.2 formulates the characteristics of the sensitivity aspects (see x-axis figure 4.1) in a more detailed way. Finally, in order to analyze sensitivity results in a systematic way and to avoid complexity, a reference situation was constructed. This reference situation, which was already described in section 4.1, is made more specific in section 4.2.3.

4.2.1 - Simulation (models) and study area

For the sensitivity analyses in this chapter two simulation models are used: a dynamic traffic assignment model called INDY (Bliemer *et al.*, 2004) and a GIS-extension called Flowmap. The dynamic traffic assignment model was extended within the OmniTRANS[79] software to model not only a dynamic route choice equilibrium, but also departure time choice and elastic demand. Figure 4.2 presents the interaction between INDY and Flowmap. The INDY modelling framework is used to forecast route travel times at different departure times before and after the introduction of a road pricing measure. In chapter 2, section 2.5.3, we explained that it is important to take into account these benefits when modelling the accessibility effects due to road pricing in a realistic way. Because of the importance of time benefits a realistic simulation of these benefits is essential, making the role of the INDY model in the analyses in this chapter a vital one. Outputs from the traffic model, in the form of travel times per network link, are used as input for Flowmap. This GIS-extension makes it possible to compute several geographical accessibility measures. Accessibility is computed both for the situation with and the situation without road pricing, using a generalized transport cost resistance function. Accessibility changes due to road pricing are then determined by the difference between both situations (with and without road pricing). The advantage of using these two models is that their strengths are combined: INDY can compute changes in traffic conditions due to a road pricing measure and Flowmap is able to compute geographical accessibility effects for groups of people living at certain locations.

In the INDY version we used it was not yet possible to distinguish different groups of people. Only one value of time is used (approximately 11 euro/hour). In addition, values for schedule

79 OmniTRANS is a software environment for transport planning and modelling (www.omnitrans-international.com).

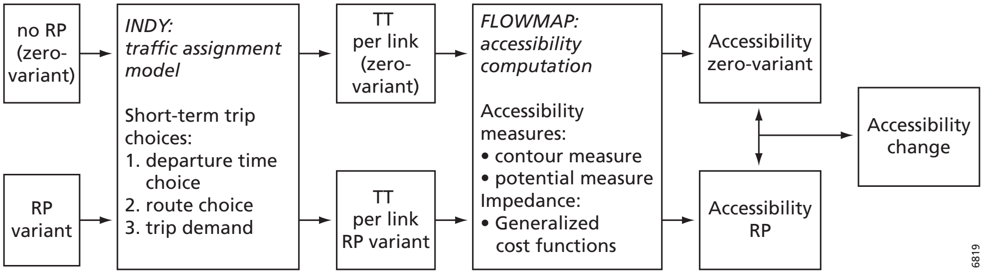


Figure 4.2: interaction process between INDY and Flowmap

delay (early and late) and a value for uncertainty of travel time were also included, again without drawing a distinction between various 'behavioural' groups. As described in section 4.1, a part of the sensitivity analysis deals with studying the sensitivity of accessibility outcomes due to road pricing to the specific value of time used. At first sight this may seem strange to do from a methodological point of view, i.e. determining travel time changes with a traffic assignment model that does not differentiate in VOT and then using these travel times in an accessibility study which studies the sensitivity to the VOT. It may, however, not be so strange at all. INDY 'delivers' the average link travel times per period. And although in reality people with, for example, a lower value of time may change their behaviour differently than people with a higher value of time, this may on average not result in (very) different average travel times within the network, compared to the situation in which one average value of time would be applied (with an average behavioural change). The accessibility (computed with Flowmap) is defined as the accessibility of a group of people with certain characteristics at a particular location and time period, given the (average) traffic situation (i.e. link travel times). Given this average travel time per link, the accessibility of people who have a higher value of time but live at the same location may experience another accessibility change as a result of road pricing than people with lower values of time (given that the link travel times are equal for both groups of people).

The characteristics of the 'Eindhoven' study area were already described given in chapter 3, section 3.4.1. The research area is regarded as a 'closed system'. This means that accessibility of opportunities such as jobs is only simulated for opportunities available within the study area[80]. In reality, accessibility may be different, because people living at locations in the research area may also look for opportunities elsewhere. This is not unique to our study, and it poses no problem in this case, where the aim is not to model the accessibility effects of road pricing for people living within the study area but rather to give an indication of the sensitivity of geographical accessibility results under road pricing conditions. For the convenience of the reader figure 4.3 shows the study area used in the simulation study, which was already presented in chapter 3. Additionally, figure 4.4 shows places in the road network of the research area where traffic congestion problems occur during periods with high traffic demand.

80 However, in the applied traffic assignment model INDY, the effects of road pricing on traffic (i) trespassing the study area or (ii) with an origin outside and a destination inside the study area and vice versa were taken into account.

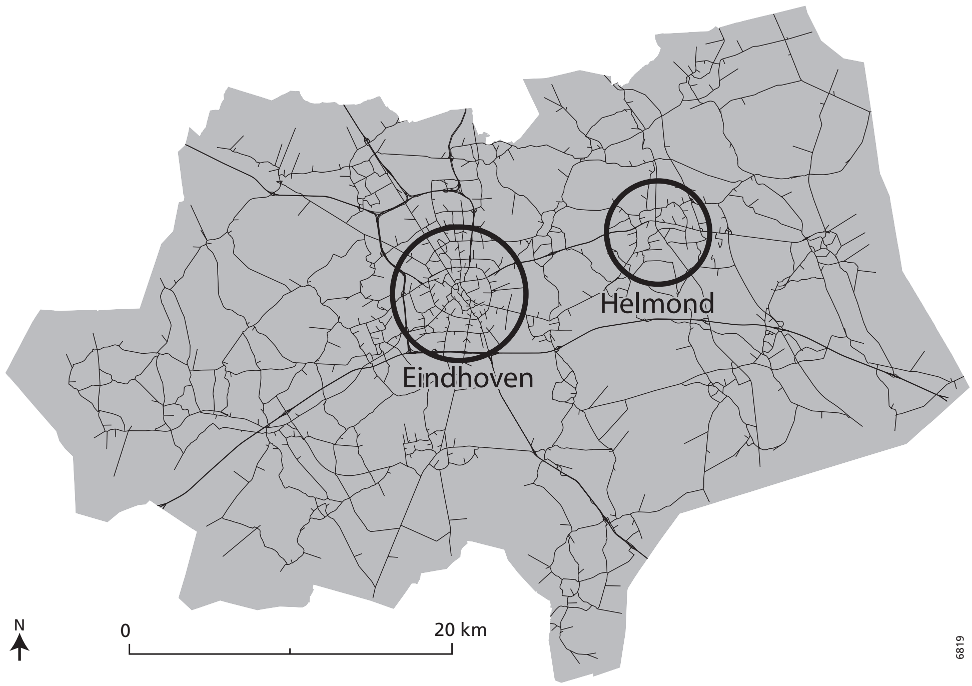


Figure 4.3: study area and network links

The total simulation period in INDY runs from 6.00 am to 10.00 am and in this case only simulates one user group, namely commuters. Because traffic has to enter the network and build up in the beginning of the simulation and has to leave the network again at the end of the simulation period, it is better to leave a part of the 4 hours out of the actual result analysis. The period for which results are checked runs from 6.30 am to 9.00 am. Simulation results are averaged for every 10-minute interval. The plan year for the simulations is 2010.

4.2.2 - Characteristics of the sensitivity analysis

Different aspects are varied systematically to gain insight into the sensitivity of computed accessibility (changes) in the case of road pricing. The sensitivity of accessibility results is studied for different accessibility measures and impedance parameters. In addition, several 'cost aspects' are varied or added, such as the type of road pricing measure (i.e. type of measure and height of charge), the size of the value of time (VOT) and the addition of a fuel cost or revenue rebate component. Finally some choices regarding network detail are discussed. All these aspects are described below.

Accessibility measures and resistance parameter

As described in section 4.1, the sensitivity of accessibility changes is studied for the contour as well as for the potential accessibility measure. Jobs are chosen as unit of analysis because an important goal of road pricing measures is to reduce congestion, and congestion generally occurs especially during peak hours (see figure 4.4). The vast majority of people driving within these periods are on their way to or on their way back from work. In reality not all jobs will be suitable

Figure 4.4: road network with congestion spots; thick black lines indicate links with a speed ratio (= actual speed/free flow speed) below 0.65.

for every person living in the study area. In effect this may influence the sensitivity of accessibility outcomes due to road pricing for different groups of people. In this study the impacts of competition and the suitability of jobs on the sensitivity of accessibility outcomes is not regarded, however, because insufficient information was available with respect to job characteristics.

An important methodological issue, not only in this study but in all geographical accessibility studies, is which type of resistance parameter should be used. The use of different resistance parameters may lead to quite different spatial patterns of accessibility. Therefore, the (spatial) sensitivity of accessibility measures to the resistance parameter used under road pricing conditions is part of the sensitivity analysis in this chapter. As far as contour measures are concerned, different impedance steps can be applied, such as cost equivalent values[81] of 10 or 15 minutes. For potential measures too, several costs sensitivity parameters can be used, such as parameter values of 1 or 2. However, in the case of potential measures the type of resistance functions is also important. Power-based and exponential functions both are often applied in practice, with each function having advantages and disadvantages (see Geurs and Ritsema van Eck, 2001; Willigers, 2006). In this sensitivity analysis it is the power function that is regarded, because in practice it may be most common to use this type of resistance function due to the correspondence between the 'original' Newtonian law of gravity, which forms the basis for the potential (gravity) based

81 A cost equivalent means that travel time impedance steps are translated into costs by multiplying the travel time with a value of time.

measures. Moreover, using both potential and exponential configurations of the resistance function would be rather time consuming. With respect to a power-based measure, a value of 1 implies a linear (proportional) impedance decay function and 2 represents a quadratic function (as in the Newtonian law of gravity) (see Geurs and Ritsema van Eck, 2001).

In this chapter the sensitivity of the accessibility outcomes (i.e. the 'spatial variation') is studied for four contour impedance steps: a cost equivalent of 5, 10, 15 and 30 minutes. Higher boundaries than 30 minutes are not included, because of the limited size of the study area and because commute trips in Holland on average do not take more than 28 minutes (CBS, 2005). For the potential accessibility measure a 'power' impedance decay function is used with three different sensitivity parameters: 0.5, 1 and 2. Values of 1 and 2 are chosen because these values are often used in practical studies. 0.5 is chosen rather arbitrarily as a third value. If the aim were to conduct an actual study into geographical accessibility effects due to a road pricing measure instead of a sensitivity analysis it would be advisable to motivate the choice of cost sensitivity parameter being used more thoroughly, for example, by calibrating the cost sensitivity factor on the basis of actual travel data.

Section 4.1 made a distinction between two directions in studying the sensitivity: (i) the sensitivity to varying aspects that are particularly important in the case of road pricing and (ii) the sensitivity to varying aspects which influence accessibility also when a non-generalized cost based function is used such as the sensitivity to the resistance parameter. To avoid making the sensitivity analysis too complicated (i.e. through many variations) the sensitivity to 'cost aspects' is studied for fixed resistance parameters. For the contour measures the average cost equivalent of 15 minutes is used because it is the average value[82] of the four impedance boundaries that were tested for determining the spatial accessibility sensitivity. However, other boundaries (e.g. 10 or 30 minutes) could have been chosen as well. A cost sensitivity parameter of 1 (i.e. a linear cost 'decay' function) is applied for the potential measure, because this value lies between the other two sensitivity parameters that were used with respect to the 'spatial variation' study.

In addition to presenting the spatial pattern of (and differentiation in) accessibility in a map, indicators are used to get a quick (aggregate) insight into the sensitivity of accessibility changes. In the case of the contour accessibility measure the following indicator is used: the average change (i.e. over all zones) in the percentage of total jobs in the study area that can be reached (by people) from an origin location. Moreover, to derive an interpretable measure to indicate the sensitivity of accessibility changes based on the potential measure, the approach proposed by Geertman and Ritsema van Eck (1995) is used. They constructed a 'modified potential measure' by computing the quotient of two classical potential formulas, whereby the resistance sensitivity parameter in the numerator is 1 point (integer value) lower than the parameter in the denominator. The outcome (in this chapter) refers to the average travel costs from a point of origin to all surrounding zone centres. By weighing this average travel cost per origin zone with the number of houses located in a zone (i.e. a proxy for the number of inhabitants) for all zones in the research area, we can give an indication of the average travel cost (per zone) in the study area, which makes it possible to determine the relative changes in average travel costs if cost aspects are varied in the sensitivity analysis. By dividing two potential accessibility measures that are in essence the same with one

82 15 minutes is the average value of the four applied impedance steps: (5 + 10 + 15 + 30 minutes)/4 = 15 minutes.

interval difference in the cost sensitivity parameter, interpretability is increased in two ways. First of all, the procedure removes the difficulty of choosing a representative cost sensitivity factor. Secondly, the spatial component (i.e. jobs) is removed due to the quotient. Because in the end only mean travel cost changes remain one may expect to find that an x-times higher charge leads to an almost x-times larger mean cost increase given the relatively limited role of travel time gains compared to charging costs.

Price levels
In section 4.1, we indicated the two types of price measures we used in the analysis: a time-differentiated kilometre charge on all roads and a time-differentiated kilometre charge on roads with a maximum travel speed of 100 kilometres per hour. The associated reference charge level amounts to 11 eurocent/kilometre in the highest demand period and 3.4 eurocent/kilometre outside that period. Furthermore, we explained why price levels are varied only for the kilometre charge on all roads. This section describes the price levels that are used in the sensitivity analysis.

The sensitivity of accessibility outcomes is tested for three price levels. As described in section 4.2.1 the total simulation period runs from 6.00 am until 10.00 am. During a one hour period (i.e. from 7.30 until 8.30 am) the highest kilometre charge is levied. This period corresponds to the period with the highest traffic demand, causing traffic congestion in the network. Before and after this period a lower charge is used. Charge levels range from relatively low to high charge levels. The first price level combination charges 2 cents outside and 6 cents per kilometre between 7.30 and 8.30 am. The second measure is the reference situation: 11 cents in the highest charge period and 3.4 cents outside that period. The third and final combination charges 24 eurocents between 7.30 and 8.00 am and 8 eurocents before and after this period. A motivation for the charge level(s) in the reference situation was provided in section 4.1. The charge levels of 6 (with corresponding 2 cents outside highest demand period) and 24 cent (and 8 cent) are chosen because they vary around the reference price level(s). The charge levels themselves are based on the levels that were applied in the time-differentiated kilometre charge in household questionnaire 2 (see chapter 3, section 3.4.4). For all price measures the highest charge level is (approximately) three times as large as the lowest one. The reason for doing this goes back to household questionnaire 2, in which behavioural changes due to pricing measures were not only examined for a time-dependent kilometre charge, but for other types of charges such as a flat kilometre charge as well. To be able to compare behavioural changes due to a time-dependent and a flat kilometre charge, price levels were 'standardized' with respect to the total kilometre charge gains of both types of measures (i.e. car kilometres driven by all respondents * charge level). Car commuters particularly drive to or from work during the high demand (peak) periods. CBS (2006) indicates that for the year 2003[83] on average approximately one-third of the daily number of kilometres driven by car drivers is to or from work. To derive the same overall price effect for the time-differentiated charge as for the flat kilometre charge the charge in the highest demand period was made three times higher than in the off-peak period.

Due to the time-differentiated price measures, the expectation is that part of the traffic demand during the highest charge period will be diverted to less expensive time periods, thus improving the traffic conditions. The modelling framework also allows for elastic demand, which results in

83 Relevant data in this area were not found for the time period after 2003.

an increase or decrease of travel demand per OD-pair, depending on the changes in generalised cost. With respect to travel demand changes two alternatives were simulated for each price measure: one with inelastic demand and one with elastic demand. The alternative with inelastic demand can be seen as a sort of lower boundary of possible travel time changes: travel time alterations only occur due to time and route changes. With regard to the elastic demand a cost elasticity of -0.2 was used. This means that a 10 percent increase in transport costs leads to a 2 percent decrease in the overall number of trips (i.e. in the OD-matrix). This demand decrease may lead to an additional reduction of congestion problems within the study area. A cost elasticity of -0.2 is quite comparable to short-term cost elasticities for fuel costs (see, for example, Goodwin *et al.*, 2004). However, a cost elasticity of -0.2 may be rather conservative in the case of a kilometre charge, since road pricing is more directly linked to travelling than fuel costs, which may lead to higher travel demand changes due to road pricing (i.e. compared to equally high fuel cost changes).

Variations in the generalized transport cost function
To test the influence of the cost function on accessibility outcomes, two stages in this simulation study are distinguished: (i) testing the effect of the value of time used, (ii) testing the effect of adding a fuel cost component or incorporating a revenue rebate.

In most cases values of time are derived from data collected in stated choice experiments. Although there are certain ranges within which values of time generally seem to fall, substantial differences between those values are still to be found. Various reasons for these differences can be mentioned. First of all, different (groups of) individuals with different characteristics may have different valuations of time, as we already mentioned in chapter 2, section 2.5.3.2. As a more methodological reason, the size of the value of time may depend on the type of choice experiment on the basis of which these values are estimated. Route choice experiments seem to yield other estimated values of time than mode choice experiments whose values again are different from values derived from departure time experiments. The research method used (e.g. stated or revealed preference), the type of estimation model applied (e.g. multinomial or mixed logit models) and the formulation of the questions in a questionnaire, however, are also methodological aspects that may affect the VOT. Finally, values of time may be influenced by other factors that are less easy to explain, such as the realism of and variation within experiments.

Because of possible large differences in values of time due to reasons mentioned above and the importance of those values for translating the resistance function of accessibility measures into financial terms, it is important to assess the (methodological) effect different values of time (in size) may have on computed accessibility outcomes under pricing conditions. On the one hand, the influence of the (monetarized) travel time within the cost function increases when the value of time is increased: the share of toll costs within the total cost function decreases. On the other hand, time gains are also valued higher, leading to higher accessibility improvements when time gains are present. The net (methodological) effect is likely to be that a higher value of time compared to a lower one would result in a relatively higher computed accessibility in the case of road pricing. However, because it is hard to make any valid comments about the sensitivity of the process in advance, the simulation study is conducted. The different values of time that are tested in the case of the contour measure are 5, 11 and 20 euro/hour. The average value of time estimated on the basis of data from a stated choice experiment in which respondents had to trade off alternative commute journeys amounts to 11 euro/hour (see, for example, Van Amelsfort and Bliemer, 2006 or Appendix C). We chose 5 euro/hour because this comes quite close to the low values of time we found on the basis of stated choice data in which people had to trade off residential locations on the basis of several house and location factors on the one hand and travel time and cost (i.e. relative to the work location) related factors on the other hand (see chapter 6, section 6.4). 20 euro/hour is chosen quite arbitrarily as a rounded maximum value of time. The average value of time for different commuter groups may, however, be (much) higher (see, for example, Van Amelsfort and Bliemer, 2006).

An issue that should be addressed here is the way the VOT is used to express travel time aspects in financial terms. In this case a VOT is multiplied with the total travel time per network link both in the situation without (see equation 4.1) and in the situation with road pricing. In the case of road pricing a toll cost component is added (see equation 4.2). This procedure (i.e. VOT*travel time) is used to convert travel times into costs. It must, however, be noted that strictly speaking the VOT (or rather the value of travel time saved) is a marginal value and does not indicate the monetarized value of a certain travel time (say 1 minute) but rather the monetary value of a certain save in travel time. As long as the value of travel time saved (VTTS) is constant with respect to travel time, meaning that the VTTS is not dependent on the actual size of the travel time, the VTTS is the same as the 'non-marginal' VOT. If the VTTS changes in time, this will also influence the non-marginal VOT. This may imply that different values of time must be used to translate different parts of the total travel time into financial terms. In this study it does not seem necessary to draw a clear distinction between non-marginal and marginal VOT, for VOT's are already varied within the sensitivity study.

$$C_{link_i} = VOT^{*}\, TT_i \qquad [4.1]$$

$$C_{link_i} = VOT^{*}\, TT_i + Ctoll_i \qquad [4.2]$$

with:
C_{link}= generalized transport costs on link i
VOT= value of time
TT = travel time on link i
Ctoll= toll costs on link i

In addition to testing the influence of the size of the value of time used, taking other components such as fuel costs into account will influence accessibility outcomes as well. By incorporating another cost component such as fuel costs (per kilometre), the relative size of the value of time in the cost function is reduced. This may influence the sensitivity of accessibility outcomes to the value of time used. A prognosis of sensitivity alterations is especially hard to give in advance in the case of using a potential measure in which the opportunities available are divided by a resistance coefficient (i.e. a quotient). The question remains whether or not it is wise to incorporate a kilometre-based fuel cost component. Fuel costs may not be valued per kilometre equally to a kilometre charge. This question, however, falls outside the scope of this chapter. The fuel cost component that is taken in account in the second stage amounts to 10.5 eurocent per kilometre. This is an average estimate of the fuel cost, taking into account the fuel prices for the various fuel types (Shell, 2006), the share of petrol, diesel and LPG cars in The Netherlands and the average fuel consumption of these cars per kilometre (computed from data provided by Schellings, 2004).

Road pricing policies will lead to revenues. The government (unless the measure is (partly) funded with private capital) can decide for which purposes to use those 'gains'. Revenues can be used in different ways, some affecting geographical accessibility to a higher extent than others. For example, using revenues to lower income taxes may have a lower impact on at least the perceived accessibility of people than if revenues are used to (partly) abolish some fixed car taxes. Moreover, as we mentioned in the case of the fuel costs, we have little idea to what extent different revenues actually influence the perceived accessibility of people. In this chapter the sensitivity of accessibility outcomes is tested for the situation in which revenues of a road pricing measure are used to: (i) abolish the (annual) fixed car taxes in the Netherlands which are dependent on the weight of the car but independent of car use and (ii) to (partly) lower fixed taxes on buying a new car. This on average amounts to a rebate of 3.4 eurocent per kilometre by car (see alternative 5, Nationaal Platform Anders Betalen voor Mobiliteit, 2005). This chapter only looks at the sensitivity of the accessibility results to an average rebate of 3.4 eurocent per kilometre[84]. However, in reality depending on the weight and the price of the car (and the settlement region), higher or lower individual rebates occur.

Detail network

The total 'Eindhoven' study area described in chapter 3, section 3.4.1 is divided into 2378 residential zones. For each zone the number of available jobs is known, making it possible to compute the job accessibility per zone. As residential zones and the road network originate from a different source, virtually no zone is directly situated 'on' the network. A common practise in such a case is to extend the network with a limited number of (441) feed points. These points are used as points where traffic can enter ('feed') the digital road network. The advantage of the feed link approach is that the network needs no further adjustments, irrespective of the zoning system used. All zones tap into the network via the feed point. This kind of simplification also decreases the computational complexity, but in effect this will generate identical distances for all zones that tap into the same feed point. Also the distance between all zones that tap onto the same feed point is by definition zero.

To take distances between zones and feed points into account a Delauney network[85] was created (see De Jong and Tillema, 2005 for a more detailed description of the procedure applied). First of all, the polygon map was updated with obstacles within the research area, such as lakes, wetlands, impassable highways and an airport. Secondly, a Delauney network was generated between the 2378 centre points avoiding all impassable areas. Finally, the Delauney network was merged with the available digital road map (see figure 4.5) leading to a 'full' network (see figure 4.6)[86]. Using this extended network instead of the simple smaller one has two implications. First of all, the impedance between two zones in general will increase (and thus accessibility will decrease) as

84 In principle, one could have objections against converting such types of revenue use into a cost rebate per kilometre. In reality, however, people may not 'feel' it in that way.

85 For an explanation of Delauney networks see, for example, Ritsema van Eck (1993).

86 As a part from the zone centre points, all feed points were also included in the Delauney network ensuring automatic connectivity with the original network.

Figure 4.5: 'small' network

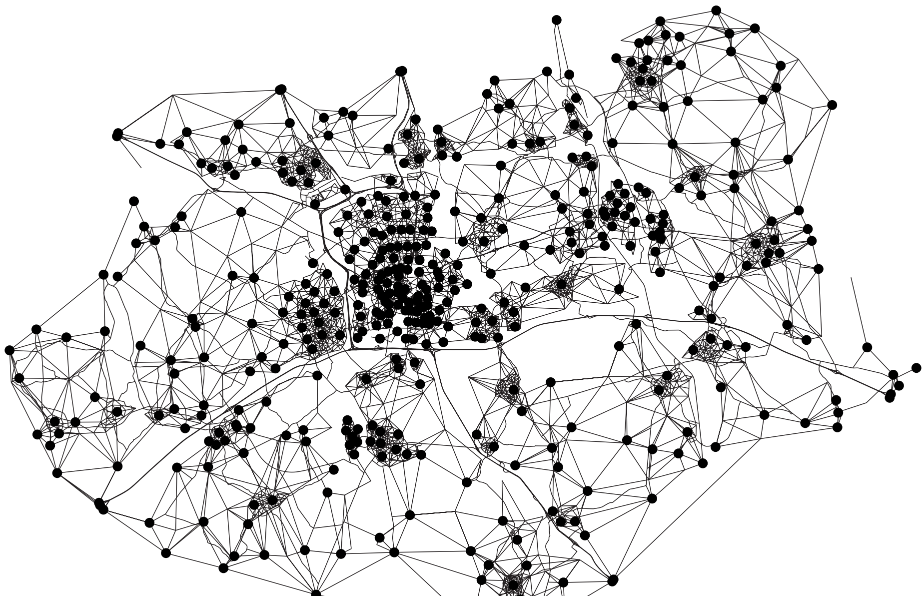


Figure 4.6: 'small' network plus Delauney sub network

distances between zones and the feed point to which they belong are no longer equal to zero. Secondly, in some situations the impedance between two zones tapping into different feed points may become smaller. This occurs when the distance following the Delauney network is shorter than the corresponding distance via the basic network. However, the exact accessibility effects and the sensitivity of accessibility measures for the network detail in case a road pricing measure is implemented can be assessed better by conducting a simulation.

From a geographical point of view, using the extended network with the more differentiated zoning system is preferable because realism is improved by linking all zones 2378 zones for which job data is available onto the network: in reality distances between the separate zones and the feed points are non-zero. In total 2819, Thiessen polygons/zones are distinguished (2378 zones + 441 feed point zones). Each polygon represents the assumed catchment area of a certain feed point. Each zone may have a different job accessibility. Within the polygons no differentiation takes place. Due to the larger number of zones a more spatially differentiated accessibility representation can be given. Because of the 'geographical preference', the extended network and the differentiated zoning system is used for the accessibility sensitivity analysis in Flowmap. The small network connecting the 441 zones is also applied, however, in a small sensitivity analysis to gain some insight into the sensitivity of accessibility outcomes to the level of network detail.

The network used in the traffic assignment model INDY is based on the 441 feed points (see figure 4.5). This can be seen as the 'small' network. Because the additional Delauney network is not included in the traffic assignment model INDY, travel time changes due to a road pricing measure cannot be computed for this additional sub-network. The assumption is made that travel speeds (i.e. 30 kilometres/hour) and thus travel times remain the same on this Delauney network both before and after road pricing is introduced. The consequences of this 'simplifying' assumption do not seem to be serious, because, as shown in figure 4.4, traffic congestion and thus possible travel time gains especially occur on motorways and not on local roads.

Simulation period sensitivity analysis
The accessibility sensitivity analysis described in this chapter focuses on the 10-minute period (in the total simulation) in which travel time gains due to the kilometre charge are highest. The idea behind this choice is that sensitivity to the value of time in such a period is largest making it possible to gain insight into 'boundaries' of the sensitivity in a better way than if periods with smaller time benefits are taken along. The largest travel time gains are expected to occur in the 'high charge period'. Partly depending on the traffic demand in the low charge period, there will be a trade-off between the price level of the charge and the resulting travel time gains. A higher charge will lead to a higher share of people changing from the high to the low charge period. However, there may be a point that so much demand is diverted that congestion occurs in the low charge period, possibly affecting travel times in the high charge period. Moreover, a high charge that leads to large travel time gains in the 'high demand' period may lead to an overall higher deterioration of traffic conditions than in the case of a lower charge if also the low charge periods are taken into account in the analysis. But as said the aim of this chapter is to gain insight into the accessibility changes. In that respect periods with high travel time gains are interesting to study.

Because of the size of the research area it is not possible to reach all destinations zones in the study area from an origin zone within 10 minutes. This means that, depending on the travel time needed to reach a certain destination, particular 10-minute periods should be combined: if someone, for example, starts driving at the beginning of a 10-minute period and has to drive 15 minutes to reach the destination that person in fact drives 10 minutes in the first and 5 minutes in the second period. Because in the chapter we only look at the sensitivity, analyses were not complicated by 'combining' periods in which people drive.

4.2.3 - Reference situation

This section formulates a reference situation on which most sensitivity analyses are based. The decision to use a reference situation was made to structure the sensitivity analysis and to avoid the number of analyses becoming too large. Whereas section 4.1 (see figure 4.1) described most of the general characteristics of the reference situation, the current section makes the reference situation more specific based on the information described in section 4.2 up to this point.

As explained in section 4.1, two price measures are used in the reference situation: a time-differentiated charge on all roads in the network and a time-differentiated charge on all roads with a maximum allowed free flow speed of 100 kilometre per hour. The charge levels for both measures amount to 11 eurocents per kilometre in the highest demand period (from 7.30 am to 8.30 am) and 3.4 cents per kilometre outside that period. For each price measure (and price level) two variants were simulated: one without and one with overall elastic trip demand. The choice was made to use the situation without elastic (i.e. inelastic) trip demand as the reference situation. It might have been more interesting to use elastic demand in the reference situation, because of the expectation that in reality a certain decrease in the overall number of trips made due to road pricing occurs as well. However, that decision was not made because initially there was some doubt as to whether the modified traffic assignment model (i.e. INDY) already handled elastic demand in a correct way. For reasons of time we decided to use the scenario with inelastic demand for the reference situation. Later on in the simulation phase the results with application of elastic demand also seemed to be realistic relative to the results with inelastic demand. As a result, we did include elastic demand in this chapter, but only in the form of a sensitivity analysis.

Table 4.1: summarized overview of characteristics of the reference situation for the sensitivity analysis

Reference situation	
Price measures	Time differentiated kilometre charge: • All roads • Roads with free flow speed ≥ 100 km/uur
Price level	11 eurocent/km during highest demand, 3.4 cents/km rest
Overall trip demand	Inelastic
Resistance parameter	One parameter per measure: • Contour measure: cost equivalent 15 minutes • Potential measure: power sensitivity parameter 1
Generalized transport cost function	Monetarized travel time and toll cost component: • VOT: 11 euro/hour
Network and zoning detail	Detailed network and zoning system

To keep the number of analyses within reasonable limits the reference situation is further narrowed down by only using one resistance parameter per accessibility measure. For the contour measure (a cost equivalent of) 15 minutes is applied as the impedance boundary value. For the potential measure a cost sensitivity parameter of 1 is used. In section 4.2.2 we explained why we chose these resistance parameters. Additionally, some choices have to be made regarding the specification of the generalized transport cost function in the reference situation. The reference specifications of the generalized transport cost function in the situation with and without road pricing were given in equations 4.1 and 4.2. The specifications only consist of monetarized travel time and a toll cost component. Other cost components, such as fuel costs, are not added. A reason for leaving fuel cost out is that it is doubtful whether fuel costs are actually perceived by people as a kilometre-based price. For the reference value of time (to express travel times in financial terms) the average estimated value of 11 euro/hour on the basis of a choice experiment undertaken in the context of this research is selected. Finally, because of the geographical 'superiority', the extended network is used linking the 2819 Thiessen polygons. Table 4.1 summarizes the characteristics of the reference situation.

4.3 - Travel time benefits and sensitivity of time based accessibility outcomes

This section focuses on travel time benefits that occur due to the different pricing measures and examines how possible travel time gains affect accessibility. Two possible effects are regarded. Firstly the strength of the effects is studied (i.e. how strongly travel time gains affect accessibility outcomes). If travel time based accessibility increases due to road pricing are large, this may imply that (for some groups of people) travel time gains for a (substantial) part compensate charging costs in cases where a generalized transport cost-based accessibility measure is used. Secondly the spatial pattern of change is examined as this gives insight into where travel time-based accessibility increases can be expected. Locations where the travel time-based accessibility increases are highest quite likely benefit the most or suffer the least from a road pricing measure. Learning more about the size of and the spatial differentiation in accessibility changes also makes it easier to analyze and explain the sensitivity of cost-based accessibility changes in section 4.4. Section 4.3.1 first describes the travel time gains. In section 4.3.2 the (time based) accessibility changes for the reference situation are examined.

4.3.1 - Travel time benefits due to the pricing measure

Travel time gains are a potential important benefit component of road pricing measures. If a pricing measure did not lead to time gains, the accessibility would inevitably decrease under pricing conditions for all groups of people (at least if revenues are not reinvested). Therefore, it is important first to assess the differences in travel times between the situation with and without pricing.

Table 4.2 indicates the observed travel time gains on the basis of origin-destination (OD) relationships by using four different indicators. These four indicators are used because together they give a more detailed insight into travel time gains due to road pricing than when they are used separately. The four indicators are: (i) the highest travel time gain found for any OD-relation, (ii) the share of OD-relationships in the study area with a travel time gain of 5 minutes or more, (iii) the percentage of OD-relationships with a travel time gain of 10 percent or more

Table 4.2: travel time gains due to kilometre charges with different charge levels (inelastic trip demand)

Travel time gain due to charge (average 10 minute period 7.40-7.50 am)	Kilometre charge all roads				Kilometre charge motorways	
	Inelastic			Elastic	Inelastic	Elastic
	6 c/km	11 c/km	24 c/km	11 c/km	11 c/km	11 c/km
Origin/destination (OD)-relation with highest time gain	8.6 min	12.2 min	14.2 min	14.9 min	19.3 min	19.8 min
OD-relations with time gain ≥ 5 min	0.5 %	0.9 %	1.3 %	1.5 %	7.9 %	9.6 %
OD-relations with time gain ≥ 10 %	1.2 %	1.7 %	6.1 %	8.3 %	22.4 %	31.1 %
OD-relations with improved travel time	90.9 %	94.1 %	98.6 %	99.7 %	68.4 %	83.7 %

relative to the situation without road pricing and finally (iv) the total share of OD-relationships for which a travel time gain is found. The travel time gains per OD-pair are determined for the 'small' network with 441 feed points. The decision to use the small network has merely two reasons. First of all, as described in section 4.2.2 travel time gains were only determined on the basis of the 'small' network with 441 feed points because this network was applied in the traffic assignment model INDY; no travel time gains are assumed to occur on the more detailed sub-network used in Flowmap (see section 4.2.2). The second reason is more practical and has to do with the size of the origin destination resistance matrices that are used for Table 4.2. On the basis of 441 feed points an OD-matrix arises of approximately 195.000 rows (i.e. 441*441). If the large network would have been used, there would have been around 6.7 million OD-relationships (i.e. 2378*2819). Even quite advanced computers had practical problems opening and analyzing these large OD-files.

It remains doubtful whether it is wise to relate travel time gains to all OD-relationships within the study area. In reality some relationships may not be important at all, for example because there are few or no jobs or inhabitants located at some origins or destinations. A preferable way of analyzing travel time gains would be to focus specifically on the most important relationships in the research area, which we did not do in this chapter.

Table 4.2 draws a distinction between time gains due to a time-differentiated kilometre charge on all roads and time gains caused by a time-differentiated charge on roads with a maximum allowed free flow speed of 100 or 120 km/hour. Moreover, a distinction is made between elastic and inelastic overall trip demand (i.e. overall trip decrease due to pricing). Travel time gains for inelastic demand are given since the reference situation assumes inelastic demand. For the reference charge level of 11 cents/kilometre, however, travel time gains are also given for charges assuming elastic demand, to gain insight into the sensitivity of travel time gains for trip demand decreases.

For all pricing measures (i.e. 2 price measures, 3 price levels and elastic or inelastic demand) the highest average 10-minute travel time gains are found between 7.40 and7.50 am. The most striking result is that the spatially differentiated kilometre charge (i.e. charge on motorways only) leads to higher time gains than the kilometre charge on all roads (based on the same price level). In the case of a charge of 11 cents/kilometre on motorways and inelastic demand almost 8 percent of the

OD-relationships experience a travel time gain of 5 minutes or more. In comparison the same charge on all roads results in roughly 1 percent of the OD-relationships benefiting with a time gain of 5 minutes or more. A difference in route changes may explain this. Route changes play a more important role in the case of the spatially differentiated kilometre charge. In the situation without road pricing congestion especially occurs on the motorways. When these motorways are being charged drivers decide more often to drive via the non-charged lower scale network. When all roads are priced people may not feel the intention to do this. Leaving aside whether or not it is desirable if a part of the car drivers divert to the lower scale roads, at least travel time gains are higher for the spatially differentiated charge. An additional effect of the spatially differentiated charge is that on the lower scale network travel times may increase to some extent due to the diversion of part of the traffic from the motorways. The fourth indicator in Table 4.2 shows this ('OD-relationships with improved travel time'): due to the kilometre charge on all roads 94 percent of the OD-relationships experience an improved travel time, whereas 68 percent of the OD-relationships benefit due to the spatially differentiated charge.

Table 4.2 indicates that, as was to be expected, higher charge levels cause higher travel time gains. The influence of the charge level, however, seems to be lower than the influence of the type of price measure. Finally, as one may expect, assuming elastic demand results in higher travel time gains. The effect of elastic demand seems to be higher than that of doubling the price level: the

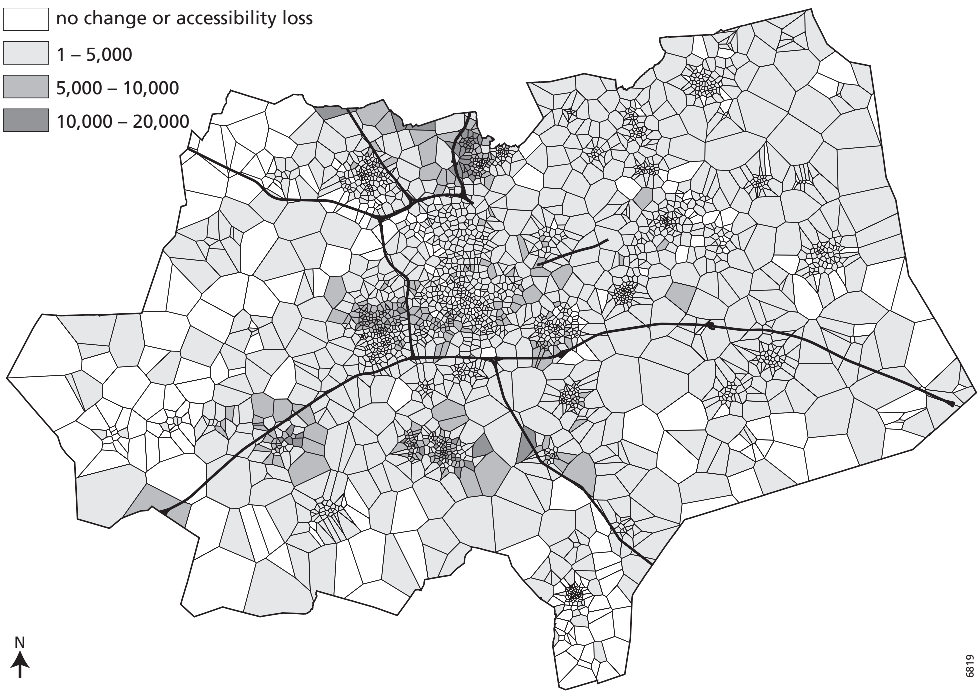


Figure 4.7: absolute job accessibility increase (number of jobs) due to time gains for kilometre charge on all roads. Contour measure with impedance step of 15 min.

decrease in travel times due to a charge level change from 11 to 24 cents/kilometre is lower than it is with elastic demand at a price level of 11 eurocents/kilometre.

4.3.2 - Time based accessibility results for the reference situation

This section describes the accessibility changes due to road pricing assessed with a time-based resistance function. In the case of the kilometre charge of 11 eurocent/kilometre on all roads on average 2,000 more jobs can be reached from a zone within the reference contour impedance step of (a cost equivalent of) 15 minutes. For the spatially differentiated charge a higher number is found: an average increase of 7,500 reachable jobs with road pricing[87].

In addition to an aggregate indication of accessibility change, the spatial pattern of accessibility change computed with a contour measure is shown in figures 4.7 to 4.10. Figures 4.7 and 4.8 present the accessibility changes due to the kilometre charge on all roads. The difference between the figures is that figure 4.7 indicates absolute changes and figure 4.8 presents relative changes. Figures 4.9 and 4.10 show the accessibility changes for the spatially differentiated kilometre charge. Unless explicitly indicated otherwise, grey and black zones represent zones for which accessibility is higher in the situation with road pricing; white zones indicate no accessibility change or an accessibility loss.

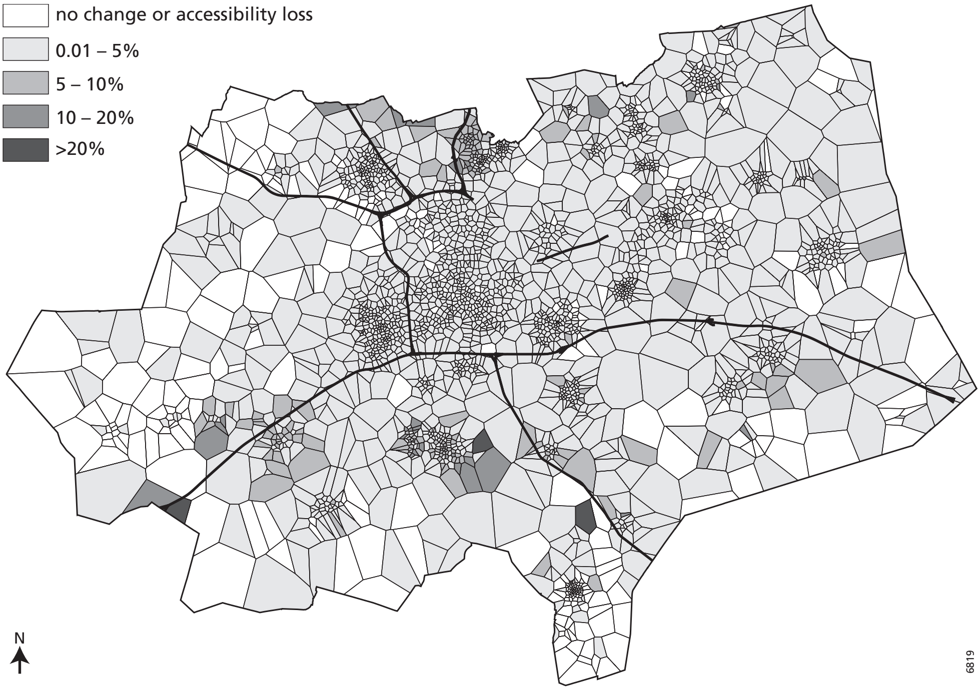


Figure 4.8: relative job accessibility increase due to time gains for kilometre charge on all roads. Contour measure with impedance step of 15 min.

87 To give a reference, the total amount of jobs in the research area amounts to approximately 395,000.

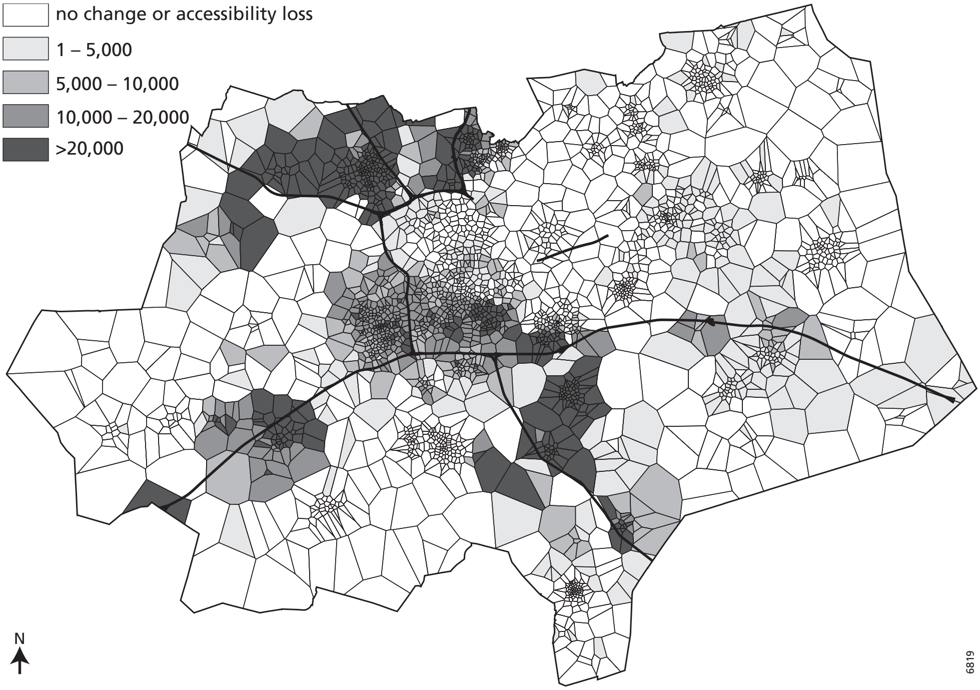


Figure 4.9: absolute job accessibility increase (number of jobs) due to time gains for kilometre charge on motorways. Contour measure with impedance step of 15 min.

Before actually describing the results, a general remark must be made regarding the zone sizes. Thiessen polygons are drawn around all 2819 zones in the study area. When zones are located close to each other, the resulting Thiessen polygon zones are smaller (Ritsema van Eck, 1993). At the fringes of the study area where the density of origin/destination points is lower, zone sizes as a consequence are often larger. This does not mean however that larger zones are more important. It may even be the other way around. In areas where the density of origin/destination points is high (i.e. representing towns/cities), the number of inhabitants and job opportunities are higher. This may make these smaller zones even more important than the larger ones. Thus, at first sight the accessibility image provided by the figures (for example figure 4.7) may be a little deceptive.

Figure 4.7 shows that in most zones the accessibility (2470 of the 2819) increases due to the time gains caused by the pricing measure on all roads. People living in the zone with the highest absolute accessibility gain can reach approximately 17,000 more job locations within the same 15 minutes. This amounts to roughly 4 percent of the jobs opportunities available within the study area. In 267 zones accessibility does not change and in 82 zones there is a decrease due to time losses. Figure 4.7 shows that especially zones in and around Eindhoven (to the south[88], east and north) benefit in an absolute sense. Due to time gains (a larger part of) the job resources

88 Valkenswaard and Eersel are villages that benefit and are situated to the south of Eindhoven; Veldhoven is an example of a town that benefits and is located to the east and Son is an example of a village that benefits and is located to the north of Eindhoven.

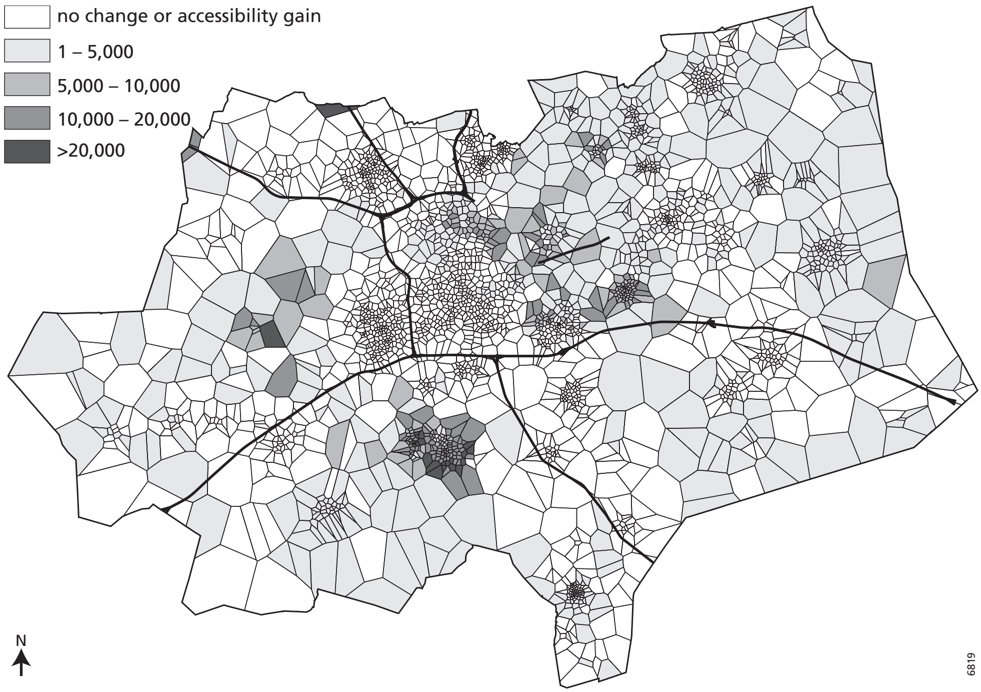


Figure 4.10: absolute job accessibility decrease (number of jobs) due to time gains for kilometre charge on motorways. Contour measure with impedance step of 15 min.

in Eindhoven come within reach for these places, as they often have a good connection to the motorways where travel time gains specifically occur. This leads to higher absolute accessibility changes in these towns. More rural regions especially in the (north) east, west and south in most case do not profit (very much). A possible explanation for this is that starting from these zones many jobs within the city of Eindhoven cannot be reached within 15 minutes, even when including time gains. This causes the absolute differences in accessibility to be lower. Subsequently, for the relative (instead of the absolute) accessibility change a very similar picture emerges (see figure 4.8), the only difference being that zones within Eindhoven improve less when the relative instead of the absolute job change is regarded. This is due to the fact that in and around Eindhoven the absolute number of jobs available is high.

The difference between figures 4.9 and 4.10, which present the accessibility changes for the spatially differentiated kilometre charge, is that grey shadings in figure 4.9 represent the accessibility gains due to road pricing whereas these shadings indicate losses in figure 4.10. The choice was made to show both situations because there are a substantial number of zones that benefit (57 percent of the zones) but also suffer (40 percent) due to road pricing. Figure 4.9 shows that, as expected, especially zones located adjacent or near to the charged roads (i.e. motorways indicated by the black lines) experience an accessibility increase. With regard to zones located in the areas in between motorways, the general accessibility decreases, as can be seen in figure 4.10. This decrease may be caused by the diverted traffic that (partly) avoids driving on the motorways due to the charge.

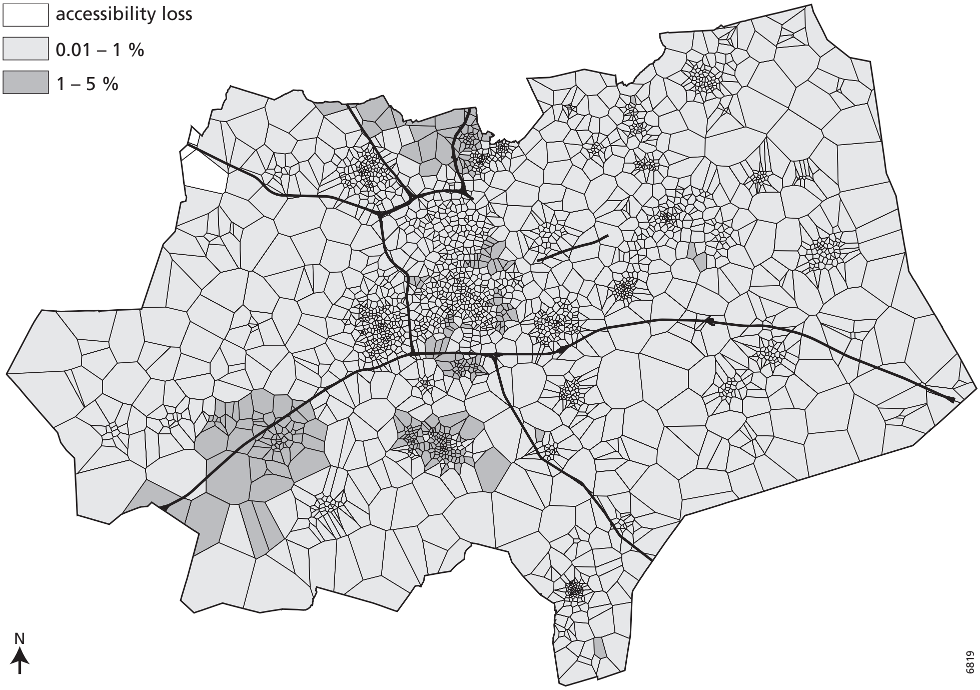


Figure 4.11: relative job accessibility increase due to time gains for kilometre charge on all roads. Potential measure with sensitivity parameter 1.

As reported before, accessibility on average increases. This can also be derived from figures 4.9 and 4.10. The number of zones with an accessibility increase is higher than the number of zones with an accessibility decrease, and furthermore, the absolute gains are higher than the losses, as indicated by the darker shadings in figure 4.9 compared to 4.10. Comparing the results for the kilometre charge on all roads and the spatially differentiated charge (i.e. figures 4.7 and 4.9) it appears that more zones have an accessibility increase due to the kilometre charge on all roads. However, the absolute gains for zones which experience an accessibility increase due to the spatially differentiated charge are clearly higher. Overall, this leads to the above-mentioned result of an average zone in the research area having a higher accessibility increase due to the spatially differentiated kilometre charge.

The results for the potential measure are presented in figures 4.11 and 4.12. Figure 4.11 indicates the results for the kilometre charge measure on all roads, and shows that accessibility increases due to time gains are (as for the contour measure) quite small. The maximum relative gain amounts to approximately 4 percent. The spatial pattern of accessibility change partly corresponds with the results for the kilometre charge on all roads described above. Due to time gains on the motorways and on the circular road around the city centre of Eindhoven the largest relative gains are again found in Eindhoven and in some places to the south and north. Except for three zones in the north-east of the study area, accessibility increases as a consequence of the pricing measure. Subsequently, grey zones in figure 4.12 denote the zones for which accessibility increases due to the spatially differentiated charge. As observed on the basis of the contour measure the highest accessibility improvements can be found along the charged motorways. Again, zones located in areas in between motorways benefit the least; in some areas accessibility even decreases. The maximum relative gain amounts to approximately 19 percent. Comparing figures 4.11 and 4.12 the same kind of image emerges as comparing accessibility changes of both pricing measures on the basis of the contour measure: due to the kilometre charge on all roads relatively more zones benefit than in the case of using a spatially differentiated charge. However, the latter charge on average leads to relatively higher accessibility gains per zone.

Overall it can be concluded that the (time-based) accessibility for the majority of zones improves. The average accessibility per zone increases by around 2,000 and 7,500 jobs for the charge on all roads and the spatially differentiated measure respectively. For the kilometre charge on all roads, the highest accessibility gains are found for zones in Eindhoven and in adjacent towns. However, as a result of the spatially differentiated measure, gains occur in particular along the charged motorways. It can also be concluded that the accessibility effects obtained by the potential measure are comparable to the results of the contour measure. Moreover, the spatial patterns of accessibility change derived from using the relative and absolute contour based change are rather similar.

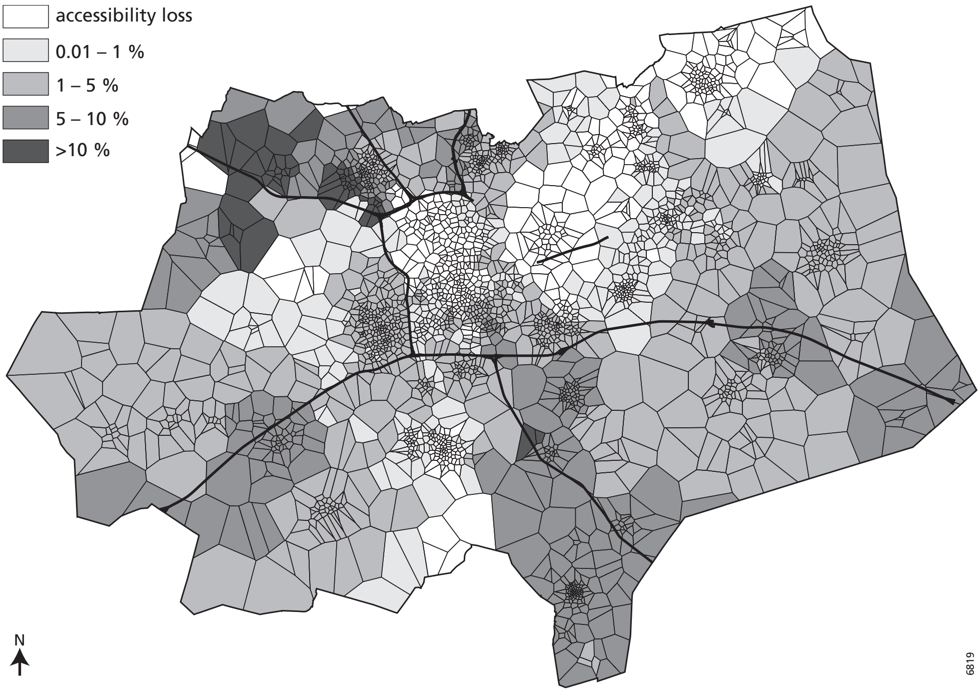


Figure 4.12: relative job accessibility increase due to time gains for kilometre charge on motorways. Potential measure with sensitivity parameter 1.

4.4 - Sensitivity of generalized transport cost based accessibility outcomes

This section focuses on the sensitivity of accessibility changes due to road pricing measures for a generalized travel cost-based resistance function in which benefits (i.e. time gains) of a road pricing measure were included. Section 4.4.1 describes the results for the reference situation (see section 4.2.3). Subsequently, section 4.4.2 presents the sensitivity of accessibility changes to several cost-related aspects: (i) the price measure, (ii) the value of time and (iii) the sensitivity to adding a fuel or revenue use component. Finally, section 4.4.3 studies the sensitivity of results to varying two other aspects which are not particularly confined to or only important in a road pricing situation: (i) the influence of the contour impedance step for contour measures or the costs sensitivity parameter for potential measures and (ii) the sensitivity of results for network detail. Results in sections 4.4.2 and 4.4.3 are separated in accordance with the two methodological paths in studying the sensitivity that were distinguished in section 4.1: aspects which are and are not specifically confined to or only important in a road pricing situation.

4.4.1 - Generalized transport cost based accessibility results for the reference situation

Results for the reference kilometre charge on all roads using the contour accessibility measure are presented in figures 4.13 and 4.14 respectively. Figure 4.13 shows the differences in *absolute* job accessibility between the situation without and with the kilometre charge. Figure 4.14 presents the *relative* changes. Grey and black areas indicate the zones with a better accessibility in the situation without road pricing: the darker the colour, the higher the differences. Figure 4.13

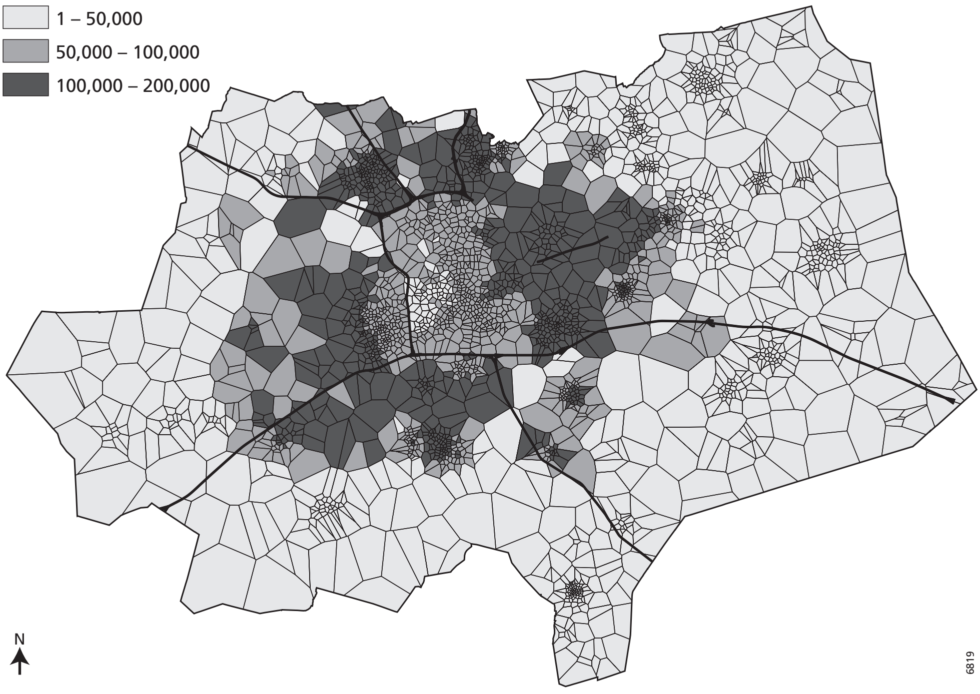


Figure 4.13: absolute job accessibility decrease (number of jobs) due to kilometre charge on all roads. Contour measure with cost equivalent impedance step of 15 min.

(i.e. absolute differences) shows that for all zones a deteriorating accessibility due to pricing is found. As can be expected on the basis of economic welfare theory, time gains (alone) due to the kilometre charge are outweighed by the costs of 11 eurocents per kilometre. The highest decrease in (absolute) accessibility due to road pricing occurs in the city of Eindhoven itself, but especially at the fringes of and in the area around Eindhoven. The more rural areas at the boundaries of the study area suffer the lowest absolute losses. A possible explanation for the 'severe' deterioration of accessibility in the area around Eindhoven is that with inclusion of road pricing the large pool of jobs in the city of Eindhoven may no longer be reachable within the chosen contour impedance step, whereas without pricing these jobs can still be reached. More rural areas often cannot reach the total 'pool' of job opportunities in Eindhoven within a cost equivalent of 15 minutes, either with or without pricing. Therefore, absolute differences in accessibility may be lower there. Section 4.4.3.1, in which the sensitivity to different contour impedance steps is studied confirms the explanations provided for the spatial trends. When the chosen contour impedance step gets larger, the highest accessibility decreases move outward to the fringes of the study area. This process ends when the contour step that is selected is so high that all jobs in the study area can be reached starting from all zones, both with and without road pricing. After that, no accessibility differences will be found. Focusing again on the situation with an impedance step of (a cost equivalent of) 15 minutes, the zone that suffers most (in an absolute sense) from the kilometre charge can reach around 170,000 less jobs. To give an indication, this amounts to more than 40 percent of the jobs opportunities available within the research area.

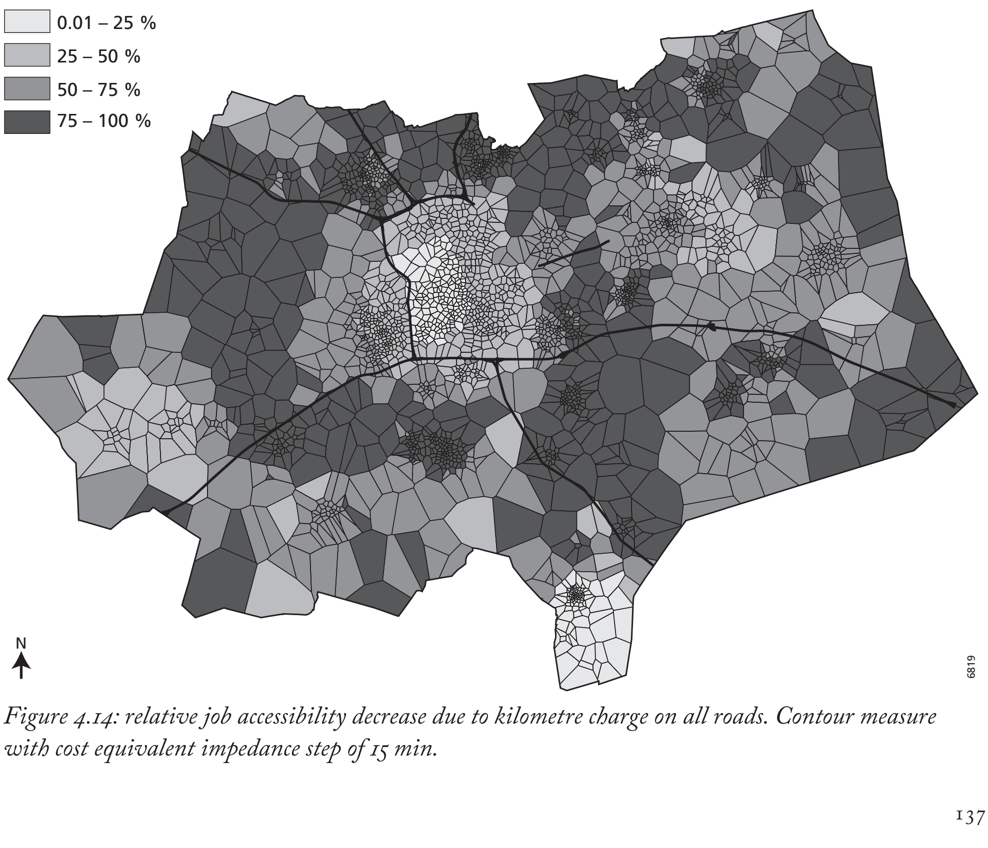


Figure 4.14: relative job accessibility decrease due to kilometre charge on all roads. Contour measure with cost equivalent impedance step of 15 min.

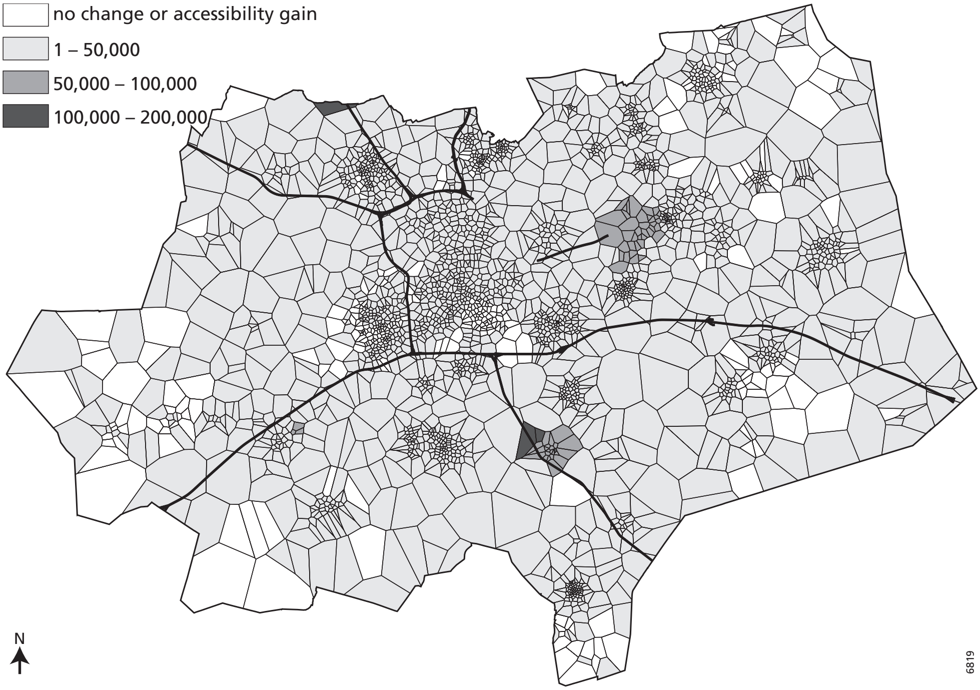


Figure 4.15: absolute job accessibility decrease (number of jobs) due to kilometre charge on motorways. Contour measure with cost equivalent impedance step of 15 min.

Figure 4.14, which presents the relative instead of the absolute accessibility changes, shows a different spatial picture. The relative accessibility due to the charge especially decreases for zones located in a wide ring around Eindhoven. A possible explanation is that from these zones the (large part of the) job resources in the city of Eindhoven cannot be reached in the case of the kilometre charge, whereas the jobs are accessible in the situation without pricing. Because a large share of the jobs that are accessible from these zones are located in or around Eindhoven the relative accessibility change for these zones is large. Within the city of Eindhoven itself, but also within the second largest city Helmond, the relative accessibility changes are lower. Although absolute changes are highest in Eindhoven (see figure 4.13), a large number of jobs in the study area (i.e. located in Eindhoven) is already accessible, both before and after road pricing has been introduced. Therefore, large absolute changes lead to lower relative changes within and just around the city. Figure 4.14 also shows that, particularly along the motorways, outward to the fringes of the research area high relative accessibility decreases occur. Possibly because of high speeds on motorways (at least if there is no traffic congestion), more distant job locations can be reached within the same costs as via lower scale roads. Without road pricing distant job locations may still be accessible compared to the situation with the charge. In combination with the lower number of jobs accessible from these rural zones (compared to zones in Eindhoven), relative differences may be high along parts of the motorways. Finally, some zones at the boundary of study area indicate a high relative decrease. This may be due to the fact that in the current situation without road pricing the job accessibility of these zones is low: within a cost equivalent of 15 minutes the job resources in the large cities cannot be reached. Then, small absolute job accessibility changes due to road pricing lead to large relative accessibility decreases.

Contour-based accessibility changes caused by the spatially differentiated kilometre charge (i.e. roads with a maximum free flow speed of 100 or 120 km/hour) are presented in figures 4.15 and 4.16. Figure 4.15 represents the absolute and figure 4.16 the relative job accessibility changes. Both figures provide roughly the same image. As could be expected, accessibility still decreases for most zones. However, compared to the kilometre charge on all roads, accessibility decreases are far lower, as is indicated by the lighter shading. Additionally, in contrast to the other kilometre charge, there appear to be zones that do not suffer (i.e. zero change) or that even benefit from the charge (the white zones). Zones that benefit are scattered across the research area, but are specifically located in and around some of the cities. Especially the southern part of Eindhoven seems to benefit. Time gains occur in that region, making jobs, at least in and around Eindhoven, more accessible. At some of the fringes of the study area, in-between the motorways, no accessibility changes due to the spatially differentiated charge occur. A possible reason is that the large job pools (especially in Eindhoven) cannot be reached both with and without road pricing. It can be concluded that the spatially differentiated charge for this study area leads to less negative (or for some zones more positive) accessibility changes, compared to the charge on all roads. This can be explained as follows. The spatially differentiated charge is levied especially in places where congestion occurs most often (i.e. motorways). Other links are not unnecessarily charged (at least from a traffic congestion reduction point of view). The

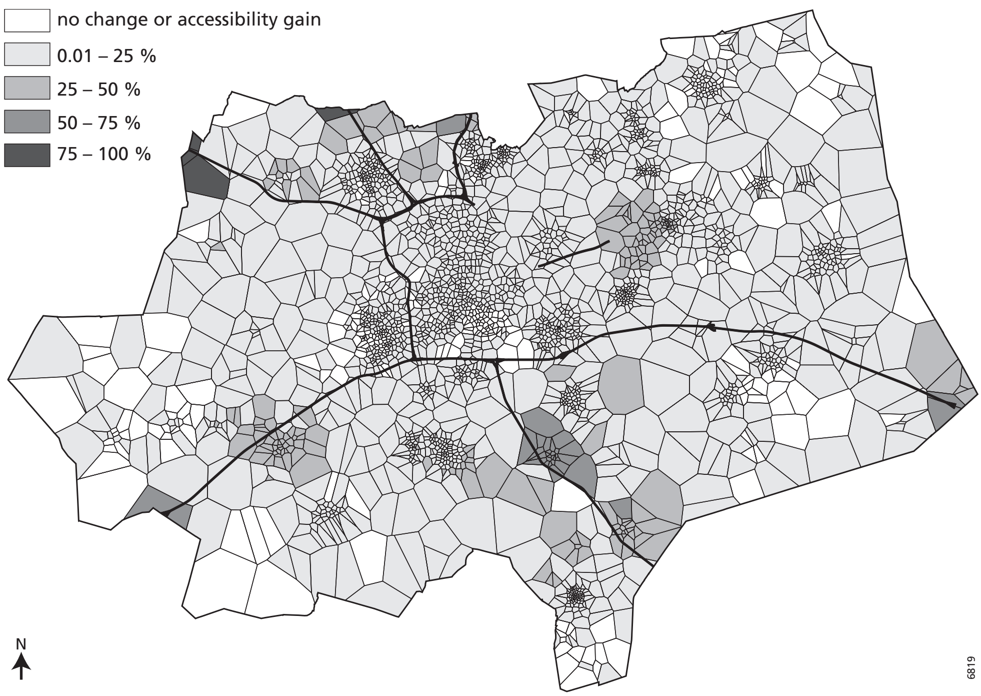


Figure 4.16: relative job accessibility decrease due to kilometre charge on motorways. Contour measure with cost equivalent impedance step of 15 min.

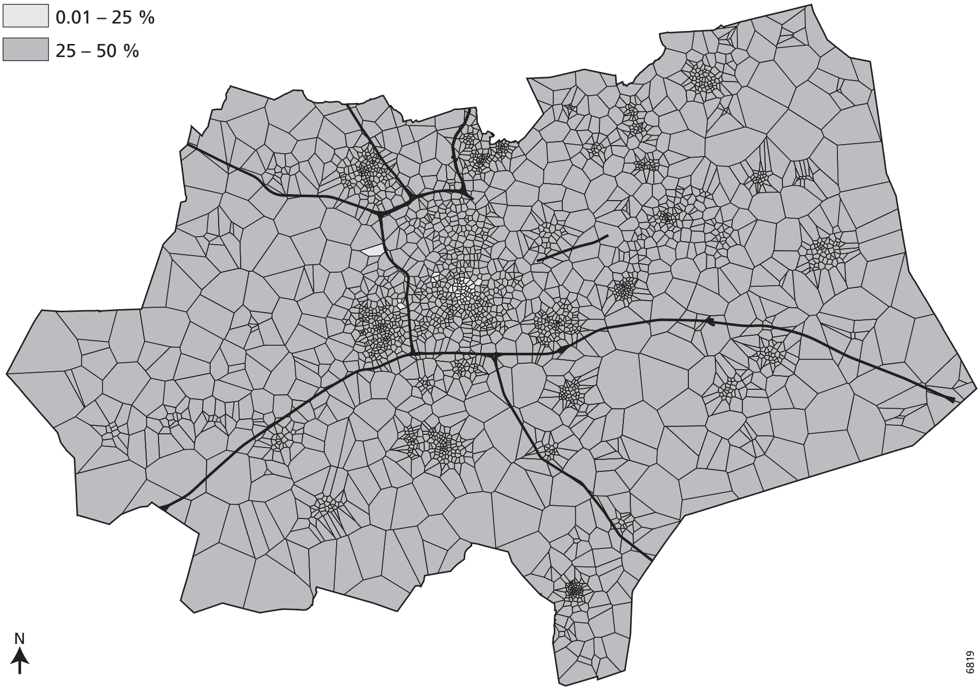


Figure 4.17: relative job accessibility decrease due to kilometre charge on all roads. Potential measure with sensitivity parameter 1.

lower charges (on average), in combination with the higher travel time gains observed in section 4.3.2, cause the spatially differentiated charge to lead to lower accessibility decreases (or higher accessibility increases) compared to the non-spatially differentiated charge.

Corresponding with the results for the contour measure, the potential measures also indicates a loss in accessibility for all zones due to the introduction of the kilometre charge on all roads. Figure 4.17 and 4.18 both present the same results, but use a different colour interval division. Figure 4.17 uses classes of deterioration with a size of 25 percent. This class division is applied to compare results with the sensitivity analysis in sections 4.4.2 and 4.4.3, where the same class division is used. Nevertheless, applying this categorization here does not lead to a differentiated picture of accessibility change. It only shows that some small zones, particularly in the city centre of Eindhoven, have a lower accessibility decrease than other zones. Figure 4.18 presents basically the same results. The difference is that four 'difference' classes are distinguished between the observed highest (45 percent) and lowest accessibility (21 percent) decrease. The classes are of equal size with respect to the 'difference range' they resemble (i.e. 6 percent).

Figure 4.18 shows a more differentiated picture than figure 4.17. The potential measure outcomes in figure 4.18 show that the relative loss of accessibility is especially lower in and in a wide area around Eindhoven. A possible explanation for this may be the fact that, as we mentioned before, a large number of jobs are available within a close range in the city and travel time gains due to the price measure are highest within and around Eindhoven. Because of the strong influence

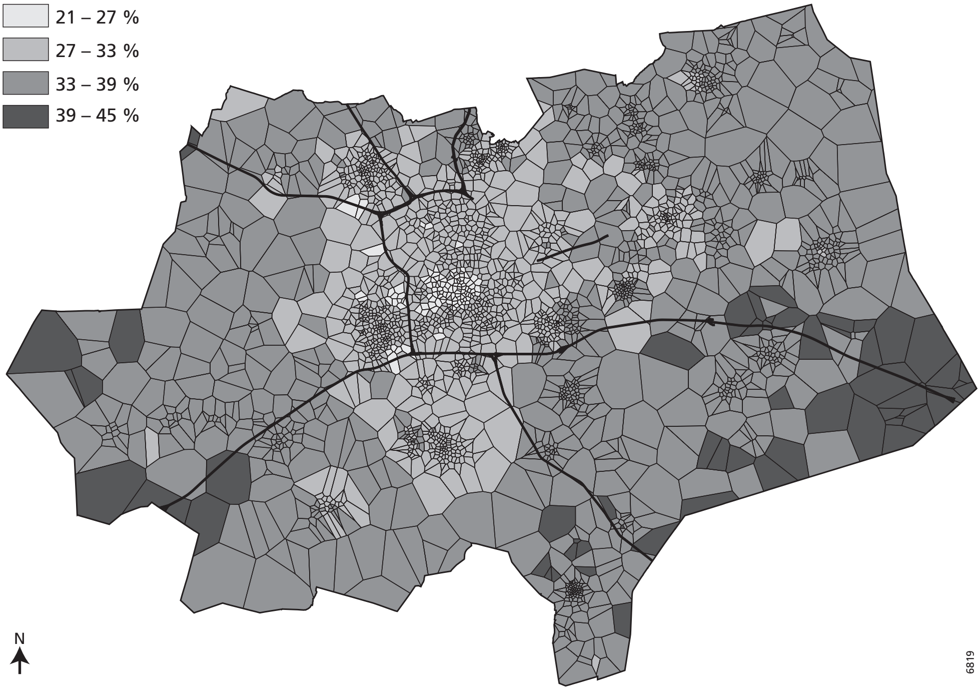


Figure 4.18: relative job accessibility decrease due to kilometre charge on all roads. Potential measure with sensitivity parameter 1.

of the kilometre charging costs in the resistance function (compared to the travel time gains), the smallest accessibility differences between the situation with and without pricing occur when distances, and thus kilometre charge costs, are relatively low. Thus, shorter distances in and around Eindhoven, in combination with the relatively higher travel time gains compared to the other parts of the study area result in a relatively lower accessibility decrease within the city. The highest relative decrease in job accessibility amounts to roughly 45 percent. Furthermore, differences in the spatial pattern of accessibility changes occur between using either the contour or potential measure. The results for the contour measure with relative accessibility changes has the highest resemblance with the potential measure outcomes. In both cases the lowest relative accessibility decrease is found in Eindhoven. However, the absolute 'contour-based' accessibility change figure (i.e. figure 4.14) shows a different spatial picture.

As was done for the kilometre charge on all roads, potential accessibility changes were computed for the spatially differentiated kilometre charge too. The results are presented in figures 4.19 and 4.20, where figure 4.19 uses the 'standard' difference classes with a size of 25 percent and figure 4.20 assigns differences to four classes of equal size (i.e. 7.4 percent), constructed between the highest and lowest accessibility change. The outcomes confirm the general conclusion drawn before on the basis of using contour measures: the spatially differentiated charge leads to lower accessibility decreases (or higher increases) compared to the kilometre measure on all roads. However, the number of zones that seem to benefit (shaded in white) is lower compared to a contour accessibility measure. In line with the contour-based results, in particular some zones in the south-eastern part of Eindhoven benefit with respect to accessibility. In addition, the spatial images provided by the potential accessibility measure for both types of kilometre charges seem to correspond: the accessibility decreases are lowest in and in a wide area around Eindhoven; the highest decreases are to be found in the south-eastern corner of the research area.

In conclusion, the spatially differentiated kilometre charge in this study scores better with respect to accessibility changes than the kilometre charge on all roads: accessibility losses due to pricing are lower (and gains are higher). Furthermore, for the aggregate impact of road pricing in this reference situation the used type of accessibility measure does not make a great deal of difference; both the contour and the potential measure indicate an accessibility decrease for most zones within the study area: in line with economic welfare analyses, travel time gains alone are not high enough to compensate for higher monetary costs due to the kilometre charge. Nevertheless, for the spatial pattern of accessibility (decrease) the use of the type of accessibility, but especially the utilized representation (i.e. relative or absolute accessibility change) do matter: the absolute accessibility decrease computed with a contour measure leads to a very different spatial accessibility pattern compared to the relative decrease. It was found that the spatial pattern of accessibility decrease computed with a potential measure shows the highest resemblance to the relative accessibility change computed with a contour measure.

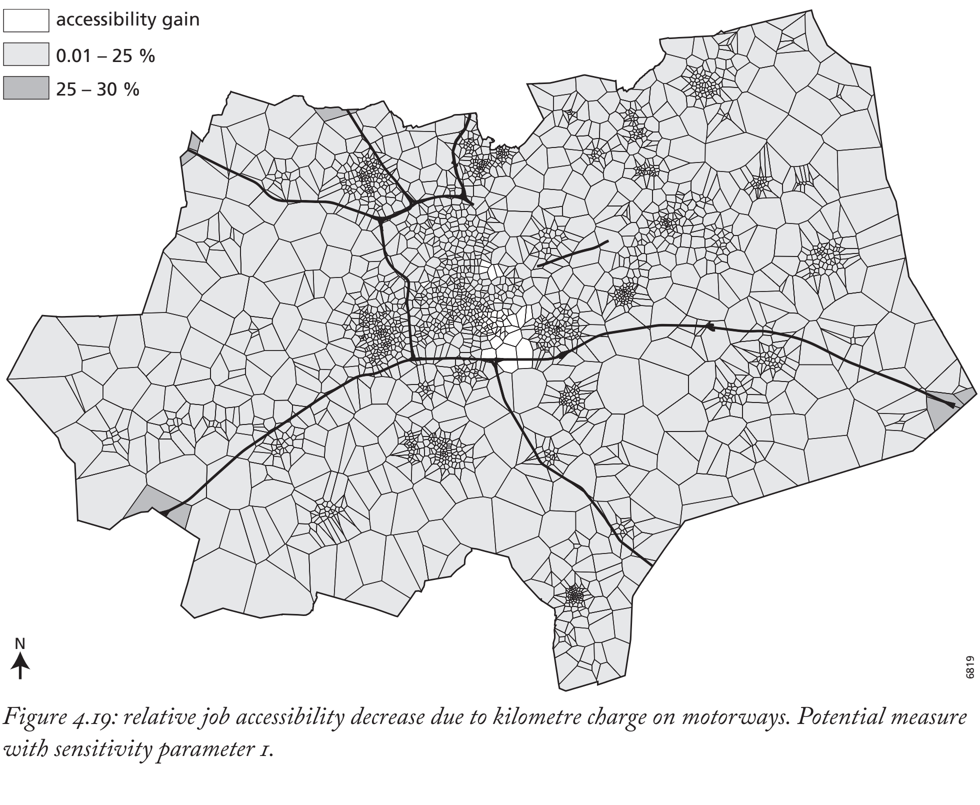


Figure 4.19: relative job accessibility decrease due to kilometre charge on motorways. Potential measure with sensitivity parameter 1.

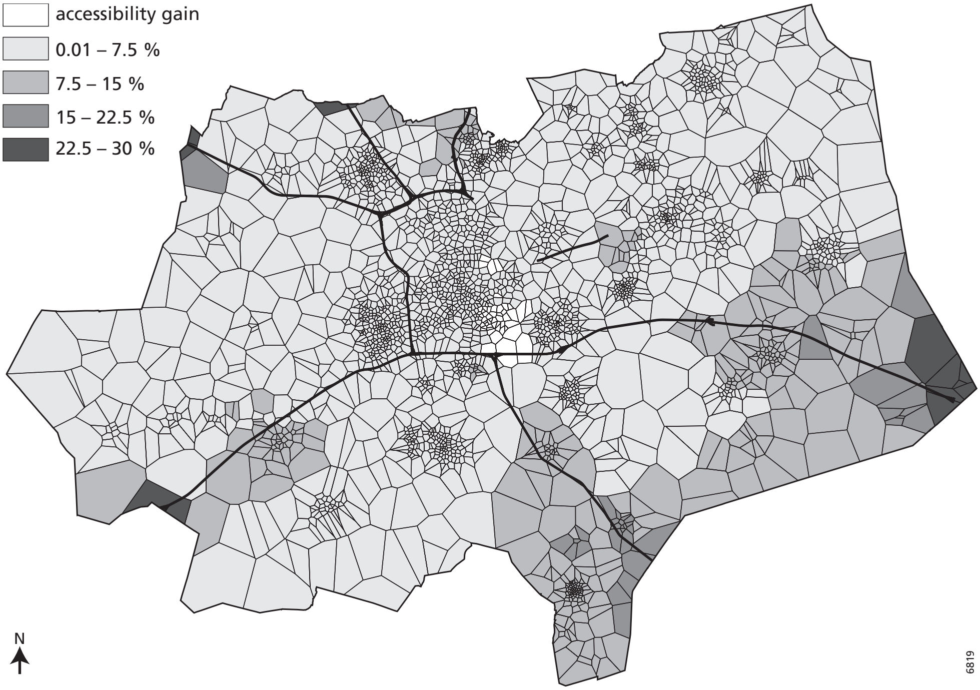


Figure 4.20: relative job accessibility decrease due to kilometre charge on motorways. Potential measure with sensitivity parameter 1.

4.4.2 - Sensitivity to cost-related aspects

This section focuses on the sensitivity of accessibility changes for cost-related aspects. Section 4.4.2.1 describes the sensitivity to the price measure (i.e. type, elasticity and price level). Section 4.4.2.2 studies the sensitivity of results for the value of time used and section 4.4.2.3 elaborates on the sensitivity to adding a fuel cost or a revenue rebate component. The motivation for studying the sensitivity to cost-related aspects was already provided in sections 4.1 and 4.2.

4.4.2.1 - Sensitivity to the price measure, elasticity and price levels

The sensitivity of accessibility outcomes was tested for two price measures (kilometre charge on all roads and a kilometre charge only on motorways) and for elastic and inelastic demand. Moreover, price levels were only varied for the kilometre measure on all roads, as was motivated in section 4.1. Figure 4.21 shows the mean accessibility change (relative to the situation without road pricing) computed with a contour measure. The different price levels are shown on the x-axis, with the most right charge level representing the charge level of the spatially differentiated kilometre measure. For every price level (and price measure) two result bars are given, one for elastic (shaded in black) and one for inelastic trip demand.

Section 4.4.1 showed that the measure with charges that apply only on motorways leads to lower accessibility decreases (sometimes even to accessibility increases) compared to a kilometre charges raised on all network links. Figure 4.21 represents this by means of one aggregate indicator: the mean accessibility change relative to the situation without pricing. The differences are considerable. The mean accessibility decrease for a charge of 11 eurocents/kilometre on all roads amounts to 60 percent (for inelastic demand), whereas for the spatially differentiated measure the average job accessibility decrease is slightly higher than 8 percent. This confirms the conclusion of section 4.4.1, that the spatially differentiated measure scores 'better'. With respect to the assumption of demand elasticity, a clear difference in sensitivity between the both price measures can be seen. For the kilometre charge on all roads the sensitivity to assuming elastic or inelastic demand is low. The difference amounts to only 1 percent for a charge level of 11 cent/kilometre (i.e. 60 percent accessibility decrease for inelastic and 59 percent for elastic trip demand). This is caused by the high influence of the charging costs compared to time gains, also when assuming elastic trip demand. On the other hand, the accessibility changes due to the spatially differentiated measure are more sensitive to elastic demand. With elastic demand the average accessibility decrease almost halves (from approximately 8 to 4 percent): because the majority of network links are not being charged, the sensitivity to travel time gains (and thus to elastic demand) plays a larger role for the spatially differentiated charge.

Three different price levels were applied for the kilometre charge on all roads: 6, 11 and 24 eurocents per kilometre between 7.30 and 8.30 am[89]. The lowest charge (i.e. 6 cents) leads to the lowest accessibility decrease. For 24 cents the decrease is highest. Bigger travel time gains caused by higher charges (see section 4.3.1) do not compensate for the extra costs per kilometre. In reality of course a charge of 24 cents will not be realistic and if such a high charge would be implemented revenue rebates would also be higher. However, the aim here is to gain insight into the sensitivity of accessibility changes to different price ranges. The average job accessibility results (inelastic demand) for charge levels of 6, 11 and 24 cents are (see figure 4.21) approximately 45, 60 and 78 percent fewer jobs accessible respectively, compared to the situation without pricing. Thus, sensitivity to the type of price measure seems to be high.

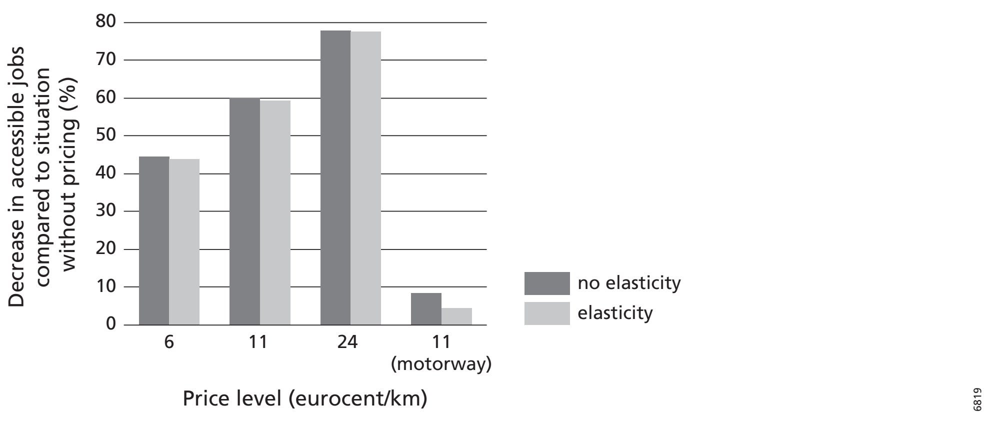


Figure 4.21: sensitivity of mean accessibility change due to pricing for the charge level. Accessibility decrease is measured relative to the situation without pricing.

89 Lower charges were used outside this period (see section 4.2.2).

As stated in section 4.1, it is hard to indicate in advance how sensitive accessibility changes are to price level alterations (see section 4.1). A charge level that is x-times higher does not seem to lead to travel time gains that are x-times higher as well: it is not a linear relationship. Particularly the kilometre costs itself are normative for the relationship between charge level and accessibility change. The generalized cost function for road pricing that is being applied is an additive function consisting of a financial travel time part and a toll element (see equation 4.2). The generalized transport cost function without road pricing that is used only contains monetarized travel times (see equation 4.1). This implies that the cost difference between equations 4.1 and 4.2 increases (almost) linearly with the charge level if travel time gains are relatively low: a price level which is twice as high leads to a generalized travel cost change which also doubles. The contour measure computes how many jobs can be reached from an origin zone within a certain resistance step within all possible directions. This means that, given that jobs and road links are uniformly spread in space, a linear increase/decrease in generalized transport costs results in a quadratic increase/decrease in accessible jobs. This does not, however, have to mean that the actual observed accessibility changes have to be quadratic as well. This in turn depends on the spatial dispersion of jobs. The jobs in the study area are not uniformly distributed in space, which affects the relationship between price level and accessibility change: in parts of the research area a certain cost reduction may lead to lower accessibility improvements than in other parts. The result of all these processes working together is that a charge that is x-times higher does not lead to an accessibility decrease that is x^2-times larger, as can be seen in figure 4.21.

In principle, the same aspects that were described above influence accessibility change computed on the basis of a potential measure: monetarized travel time (gains), influence of travel time and charge levels on the sensitivity of the generalized transport cost function and, finally, the spatial dispersion and the number of jobs locations. From a theoretical point of view the impact of increasing the charge level would have a different impact on potential-based compared to contour-based accessibility. Potential accessibility is computed by the quotient of jobs available and the generalized transport cost. If a linear cost sensitivity parameter is assumed and the base situation remains unaltered then a charge that is x-times higher results in a relative accessibility decrease of less than x-times higher. Instead of a quadratic impact of charge level on potential accessibility change, a more natural logarithmic relationship is expected, at least if jobs are assumed to be evenly spread across the study area which, is not the case here.

To make results easier to interpret mean travel cost changes were computed on the basis of the quotient of two potential measures and by weighing outcomes with the number of houses (i.e. as a proxy for inhabitants). This procedure was described in section 4.2.2. The outcome of this procedure is the mean trip cost change per zone due to road pricing. The sensitivity of the change in mean trip cost due to the type of price measure, demand elasticity and price level is presented in figure 4.22. The figure shows that, as observed for the contour measure, the sensitivity of results to the assumption of demand elasticity is low, at least for the charge on all roads. More striking is that the average transport cost increases (expressed in percentages) are lower than the decreases in job accessibility in figure 4.21. This may be due to the fact that jobs are not uniformly distributed in space. In the case of the procedure of dividing two potential measures, this spatial job component is (mathematically) 'deleted'. Moreover, for the differentiated charge the average transport costs even seem to decrease slightly due to the introduction of pricing. However, these cost decreases are small (around – 0.15 percent for inelastic and – 0.32 percent for elastic demand).

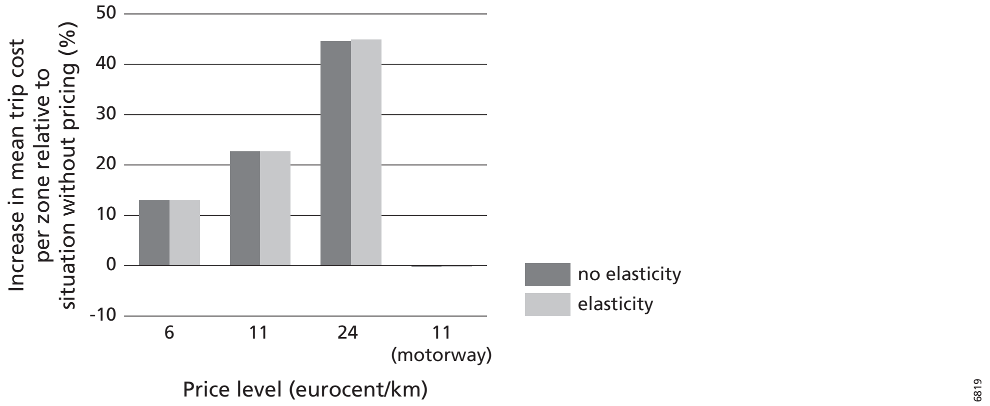


Figure 4.22: sensitivity of increase in mean trip costs due to pricing for the charge level.

The relationship between charge level and mean trip cost change can also be derived from figure 4.22. The average increase in mean trip costs for people living in the research area amounts to 13 percent with a charge level of 6 eurocents/kilometre. For a charge of 11 cents this increase is around 23 percent. The highest decrease is found for the highest charge of 24 eurocents per kilometre: an increase of approximately 45 percent in average costs. This relationship looks rather linear: from 6 to 11 cents the average trip cost increase almost doubles and the cost increase with 24 eurocents/kilometre is approximately three times higher than with 6 cents.

Additional to more aggregate indications of change, such as the mean accessibility change or average trip cost alteration, the spatial pattern of accessibility may be sensitive to price measure characteristics as well. The spatial sensitivity to changing the type of price measure (spatially and not-spatially differentiated charge) was already described in section 4.4.1. Moreover, the spatial sensitivity to demand elasticity was found to be low for the charge on all roads and as a consequence is not represented graphically. However, the spatial sensitivity to assuming trip demand elasticity is considerably high for the spatially differentiated charge. Figure 4.23 provides some insight into this sensitivity to contour-based results. The figure shows that the number of zones benefiting from road pricing increases substantially when trip demand is assumed to be elastic. Similarly, the potential measure based accessibility results, which are not shown here, are sensitive to elastic demand as well.

The sensitivity of the spatial pattern to the charge level was also studied for the contour measure (absolute and relative change) as well as for the potential measure (i.e. on the basis of the kilometre charge on all roads). The general image of the 'spatial' sensitivity of results is roughly the same for both accessibility measures, which is why only results for the contour measure are shown in figure 4.24. As described above, the general picture is that accessibility changes are bigger if the charge level is higher, although if the spatial sensitivity is defined as accessibility for one zone changing differently than for another zone, the spatial sensitivity is quite low; the spatial pattern is quite consistent. Zones, which already experience a higher general accessibility decrease, keep a higher decrease when the charge level is varied within the boundaries of the sensitivity analysis.

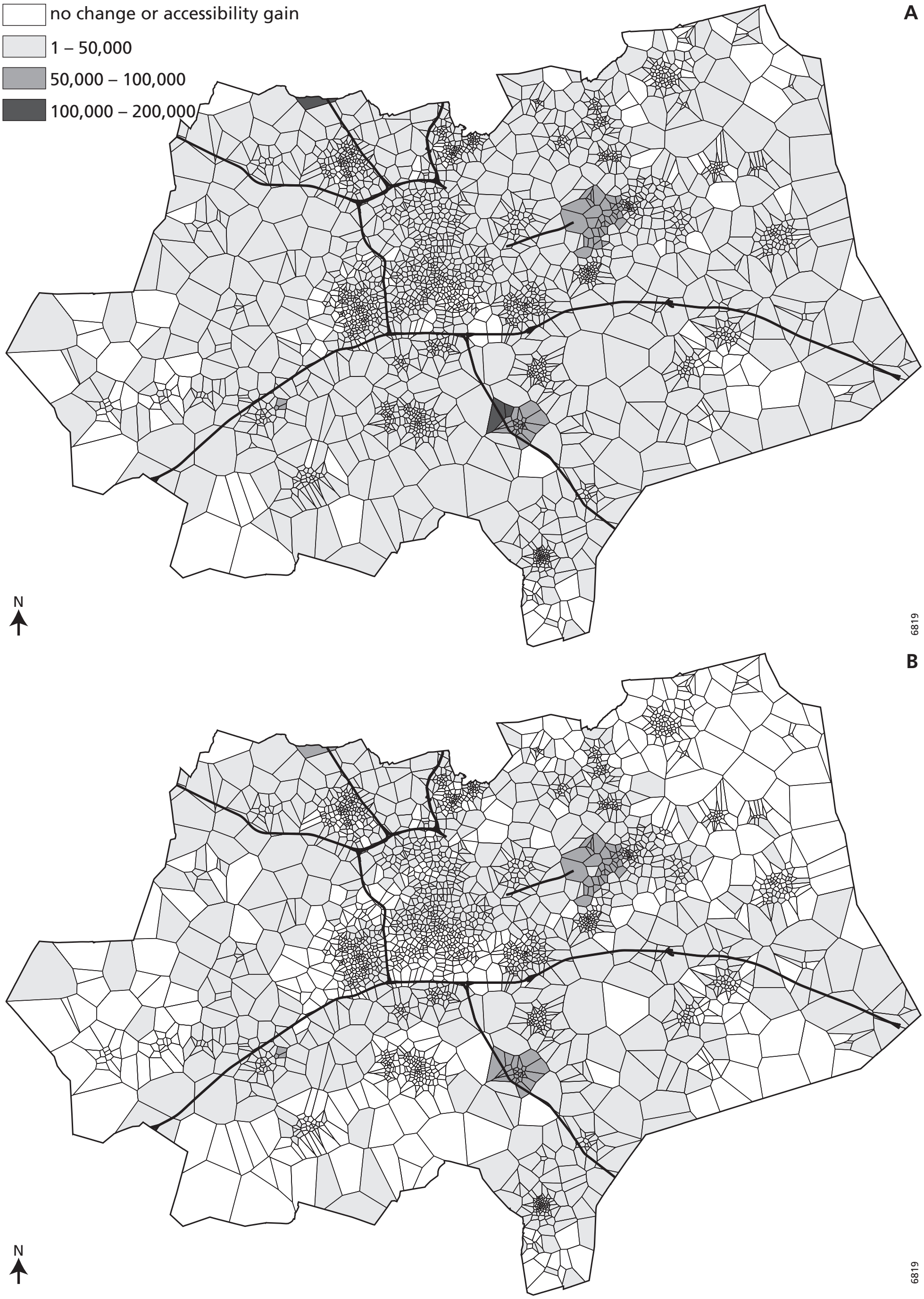
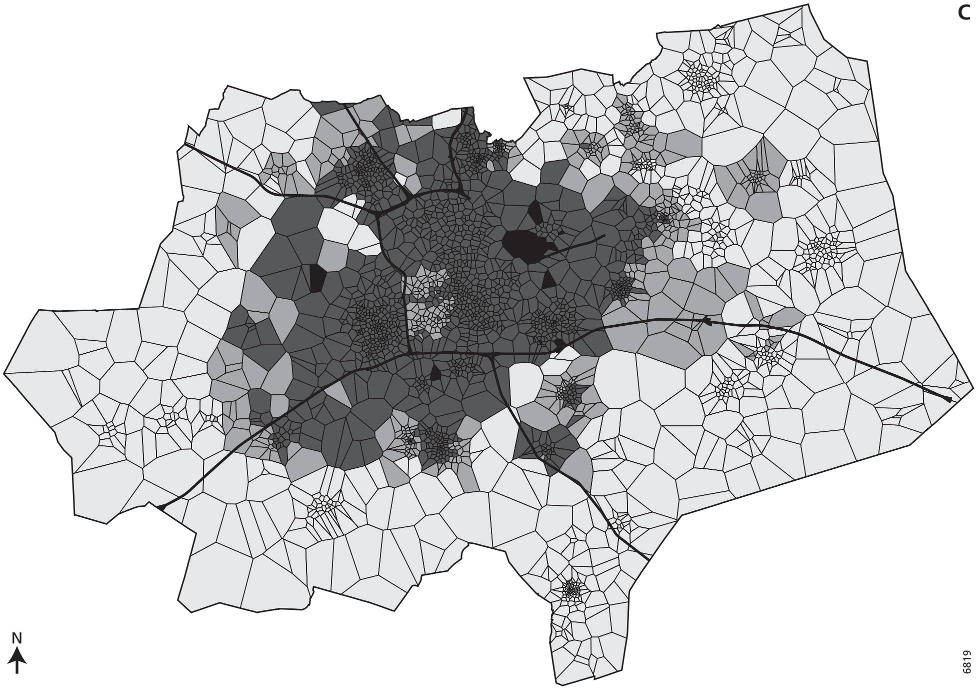


Figure 4.23: absolute job accessibility decrease (number of jobs) due to kilometre charge on motorways differentiated towards elastic and inelastic trip demand. Contour measure with cost equivalent impedance step of 15 min. A: inelastic trip demand. B: elastic trip demand

Figure 4.24: absolute job accessibility decrease (number of jobs) due to kilometre charge on all roads. Contour measure with cost equivalent impedance step of 15 min. A: charge 6 eurocents/km. B: charge 11 eurocents/km. C: charge 24 eurocents/km



It can be concluded that the sensitivity to price measure characteristics is large. As was shown in section 4.4.1 and confirmed in this section, a time-differentiated kilometre charge that additionally is levied only/especially on traffic congestion sensitive points in the network has higher positive (less negative) accessibility effects compared to a kilometre charge that is not spatially differentiated. Moreover, the sensitivity to assuming elastic traffic demand (leading to higher travel time gains) proved to be substantial only in the case of the spatially differentiated charge. This can be explained as follows. On most roads (especially of the lower scale network) there are no travel time gains, since there is no traffic congestion. This makes a charge that is levied on all roads less effective: people have to pay on roads where there are no benefits. As a consequence, charging costs dominate monetary time benefits more strongly. In addition, the sensitivity to the charge level was tested for the kilometre measure on all roads. Higher monetarized travel time gains due to higher charges do not compensate for the extra costs of such a higher charge. This results in higher accessibility decreases for higher charge levels. The sensitivity to price level was not studied for the spatially differentiated charge (see motivation section 4.1). It is, therefore, hard to predict to what extent sensitivity results would be different compared to the results for the charge on all roads. It is expected that accessibility changes due to the spatially differentiated charge will be sensitive to the applied charge level, as was found for the kilometre charge on all roads. The sensitivity may even be higher, since the sensitivity of accessibility changes for assuming demand elasticity was found to be higher in the case of the spatially differentiated charge. Nevertheless, additional research is needed before any definite statements can be made. Finally, we found that, for the contour measure a charge that is twice as high does not lead to an expected quadratic accessibility change. This may to a large extent be caused by the spatial configuration of jobs.

4.4.2.2 – Sensitivity to the value of time

As described in section 4.1, three values of time were applied in the sensitivity analysis: 5, 11 and 20 euro/hour. To give an indication of the sensitivity, figure 4.25 shows the average job accessibility change per zone differentiated towards value of time and type of price measure. Results for the price measure on all roads are shaded in black and the striped bars represent the kilometre charge on motorways. The general picture for both price measures is the same: accessibility decreases are smaller for higher values of time, due to the fact that two different effects reinforce. Application of a higher value of time causes the relative influence of road pricing costs in the generalized transport cost function to decrease, which makes accessibility decreases due to pricing lower. In addition, time gains are valued higher in the case of a higher value of time, resulting in a lower accessibility decrease.

For a value of time of 5 euro/hour and a contour impedance step of (a cost equivalent of) 15 minutes the accessibility decrease due to the charge on all roads (compared to the situation without pricing) amounts to 78 percent. For values of time of 11 and 20 euro/hour this average difference relatively decreases to approximately 60 and 45 percent. For the kilometre charge on motorways the accessibility decreases are lower again. For values of time of 5, 11 and 20 euro/hour the observed accessibility decreases are roughly 9.5, 8.3 and 5.9 percent. Thus it can be concluded that overall accessibility outcomes are sensitive to the VOT.

Even when the VOT is high (i.e. 20 euro/hour), monetarized travel time gains due to the price measure alone do not compensate for the kilometre charge costs. Thus, only for groups of people with very high values of time, travel time gains alone may increase their accessibility in the case of a kilometre charge on all roads. Figure 4.26 shows that, as far as the reference situation described in section 4.2.3 is concerned, the trade-off value[90] of time for which almost the same number of zones benefit and suffer from the kilometre charge of 11 cents is close to an unrealistic 1250 euro/hour. However, when elastic trip demand is assumed, causing higher travel time gains, the

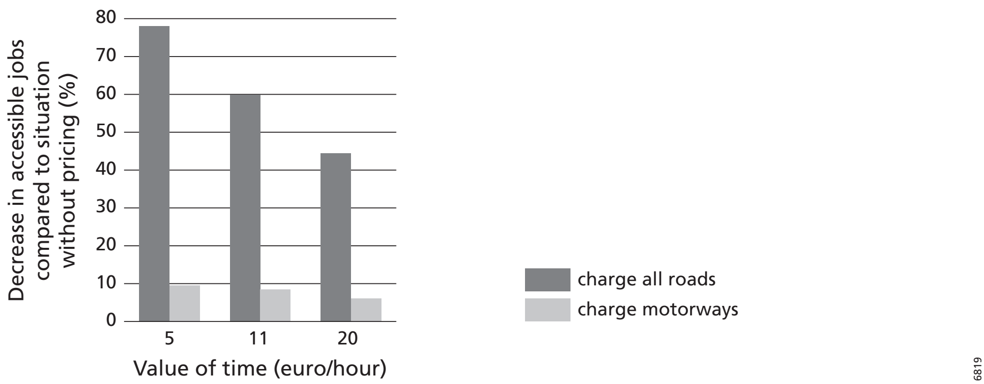


Figure 4.25: sensitivity of mean accessibility change due to pricing for the VOT. Accessibility decrease is measured relative to the situation without pricing.

90 The trade-off value of time is characterized in this chapter as the value for which the same number of zones experiences an accessibility benefit and suffers from a pricing measure.

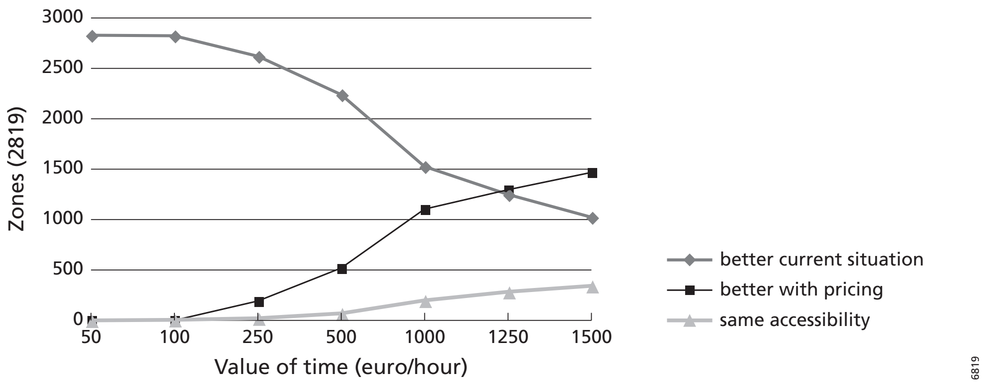


Figure 4.26: trade-off value of time for reference situation (i.e. charge 11 eurocents/km, no elasticity); number of zones with better/same accessibility: contour measure 15 minutes

trade-off value of time already decreases with a factor of 5 to 250 euro/hour. With regard to the kilometre charge on motorways it is a different story. The trade-off value of time for assuming inelastic demand amounts to roughly 100 euro/hour, whereas for assuming elastic demand the value decreases to approximately 20 euro/hour, which comes close to 'realistic' values of time for some groups of people (e.g. time-pressured commuters, business travellers).

As before we computed the mean change in trip cost on the basis of the quotient of two potential accessibility measures. Again the same kind of sensitivity can be seen for the kilometre charge on all roads: the mean trip cost increase due to the kilometre charge becomes smaller with increasing VOT, but for 20 euro/hour still a trip cost raise is observed for all zones. The average increase in mean trips cost due to road pricing for someone living in the research area amounts to 23 percent if a value of time of 11 euro/hour is used. For values of time of 5 and 20 euro/hour the mean increases are 45 and 13 percent respectively (see figure 4.27). In contrast to the contour measure based results, increases in mean trip cost are lower in proportional size than decreases in accessibility. As indicated in the previous section, this may be due to the spatial configuration of jobs that are left out in the case of dividing two potential accessibility measures.

Moreover, mean trip cost changes due to the (differentiated) kilometre charge on motorways were computed (see figure 4.28). The figure shows a counterintuitive image. The mean trip cost decreases due to pricing (compared to the situation without road pricing) are higher for lower values of time. In other words, although differences are small, a lower value of time leads to a more 'preferred' result. However, when accessibility changes due to road pricing are evaluated for different values of time on the basis of the two single potential accessibility measures separately (i.e. the ones that are used in the division process to obtain insight into mean trip cost changes) then results are again as expected: a higher value of time results in lower accessibility decreases (or higher increases). Thus, something 'strange' happens when dividing two potential accessibility measures according to the procedure described by Geertman and Ritsema van Eck (1995). Closer examination of the results shows that this strange result is primarily caused by 'rerouting'. As described before, the relative influence of charging costs in the generalized transport cost function decreases when the applied value of time increases. This also means that, in the case

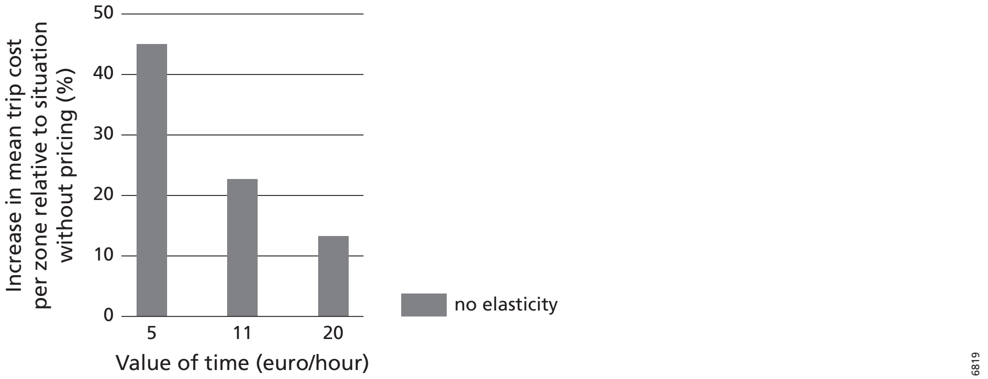


Figure 4.27: sensitivity of increase in mean trip costs for VOT variation. The used charge is the kilometre charge on all roads.

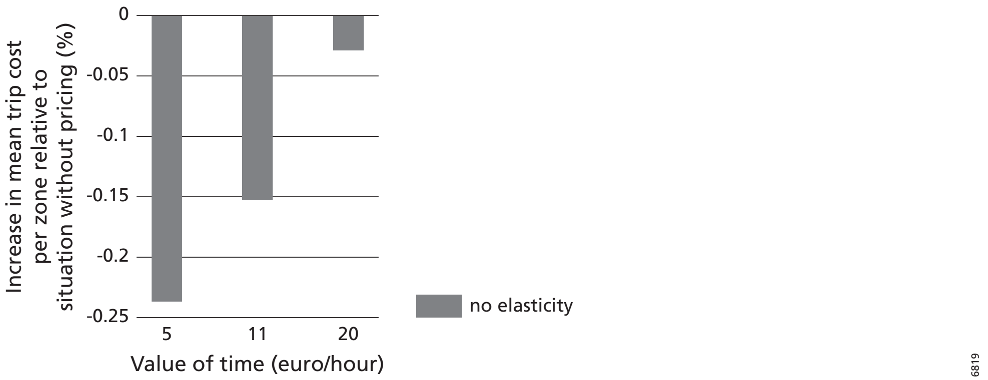


Figure 4.28: sensitivity of increase in mean trip costs for VOT variation. The used charge is the kilometre charge on motorways.

of a higher value of time, people are less motivated to try to avoid driving on the motorways where the charge is levied (at least if there is not much congestion). When lower values of time are applied (e.g. 5 euro/hour) people try to avoid driving on the motorways. In the case of the applied higher values of time, the routes people drive are more similar to the ones without road pricing (i.e. compared to what happens when lower values of time are used). Overall, this results in mean trip cost changes being dampened out for higher values of time: the highest increases and decreases in mean trip cost are both lower than for lower values of time. In the computation of the mean trip costs, where potential accessibility measures with linear and quadratic transport cost functions are divided, this leads to a strange situation whereby for some zones a higher mean trip cost decrease is found for a higher value of time, whereas for another zone a lower value of time leads to better results. Because of the complicated dividing process it may be concluded that the method of computing mean trip cost changes by using a quotient of two potential accessibility measure is less suitable in situations with complex (behavioural) relationships, such as in the case of road pricing.

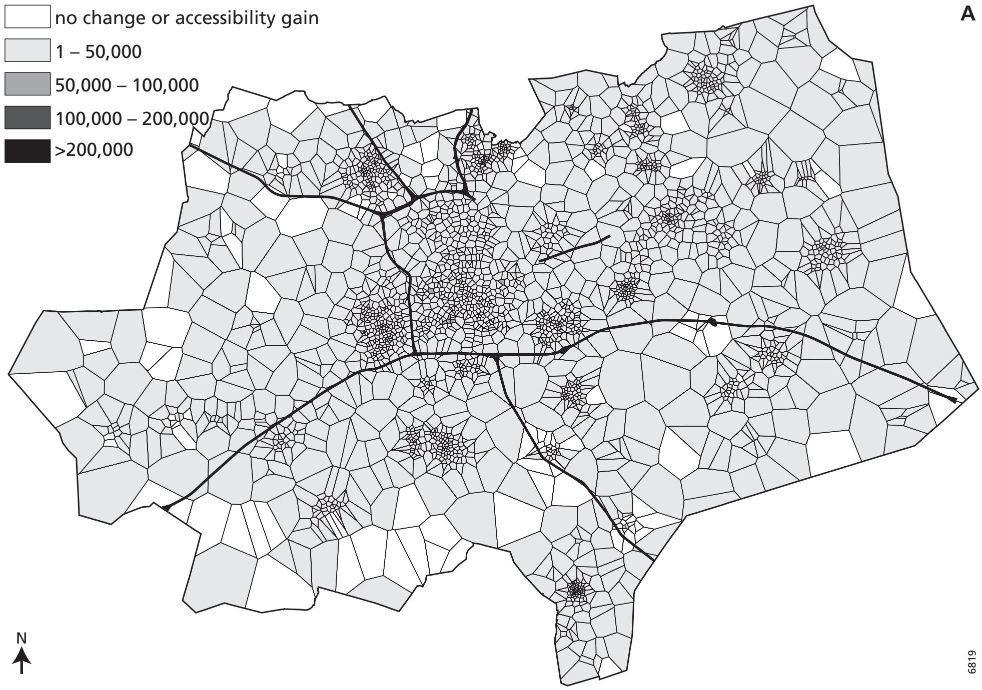
Furthermore, in essence the sensitivity of accessibility changes for a change in the VOT is the same as for a comparable change in the charge level. Since the sensitivity to VOT is in fact is the same as the sensitivity to charge level, spatial sensitivity results are not shown here.

It can be concluded that accessibility outcomes due to road pricing are sensitive to the value of time used. As expected, a higher value of time in general results in lower accessibility decreases or higher increases compared to lower values of time. This is especially caused by the fact that a higher value of time makes the influence of charging cost in the generalized transport cost function lower. Additionally, the higher valuation of time gains when using a higher value of time plays a role in making accessibility decreases lower (or increases higher). Moreover, in line with economic welfare analyses we found that, within a range of realistic values of time, time gains alone do not (by far) compensate the extra charging cost due to a kilometre charge on all roads. On the other hand, for the spatially differentiated kilometre charge (with assumption of elastic demand) the trade-off value of time is close to realistic average values of time. In such a situation the accessibility of groups of people with higher than average values of time may increase. This is, however, also strongly spatially dependent: some locations benefit more than others.

4.4.2.3 - Sensitivity to adding a fuel cost or revenue use component

As motivated in section 4.1, the sensitivity of accessibility outcomes to adding a fuel cost or revenue use component is only studied (superficially) for one charge, i.e. the kilometre charge on all roads. To determine the sensitivity of accessibility outcomes to fuel costs, an average fuel cost of 10.5 cents/kilometre is added to the resistance function (see section 4.2.2). By adding a fuel cost component, accessibility decreases due to the road pricing measure seem to get smaller when a contour measure is used. This result may be somewhat misleading. Since the same fuel cost component is added both in the situation with and without pricing, the cost resistance between two zones in fact is increased with a constant value (i.e. distance * fuel cost per kilometre). Then, in order to realise the same outcomes due to pricing as observed without adding a fuel cost, the impedance step used for the contour measure should also be increased. Thus, the sensitivity of accessibility outcomes based on a contour measure in fact does not change due to the addition of an extra cost component. It is rather a difference of scale problem. For the potential measure, sensitivity results are somewhat different. In fact, two processes play a role. First, due to the addition of a fuel cost component, the available opportunities are divided by a higher resistance both with and without road pricing. The higher influence of resistance causes accessibility differences between the situation with and without road pricing to get more local (as also happens if a higher resistance parameter is chosen). In addition, however, the accessibility decrease due to pricing is relatively lower because the (constant) opportunities are divided by a higher resistance.

Subsequently, the sensitivity was studied for a reduction of the kilometre costs of 3.4 cents per kilometre (see section 4.2.2). In the end this rebate causes the same time gains to be reached against lower costs: for example, in the case of a kilometre charge of 11 cents/kilometre, drivers effectively only have to pay 7.6 cents per kilometre. The same type of sensitivity occurs as for the change in charge level described in section 4.2.2.1. The logical effect of such a rebate component is that the accessibility decreases become smaller and the effects are rather sensitive to such rebates.



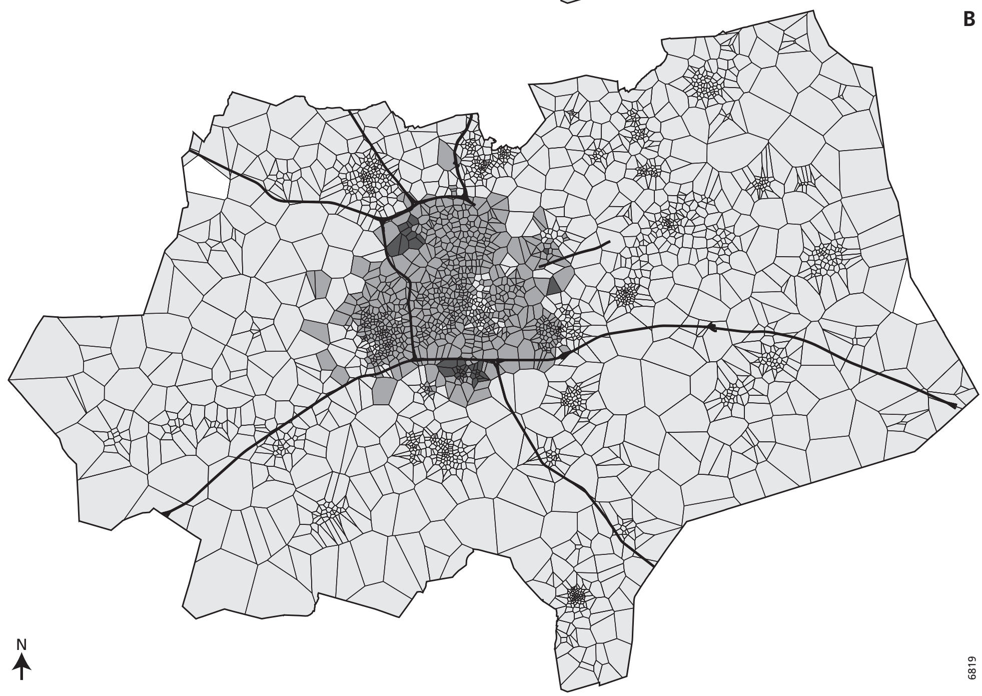
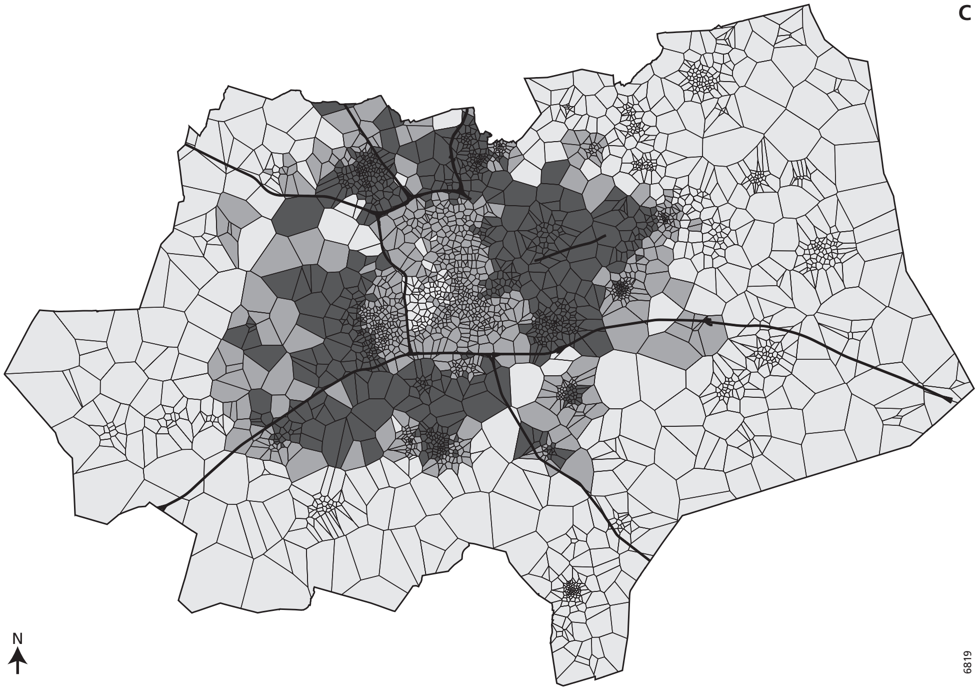


Figure 4.29: absolute job accessibility decrease (number of jobs) due to kilometre charge on all roads. Contour measure with different (cost equivalent) impedance steps. A: 5 minutes. B: 10 minutes. C: 15 minutes 4.29. D: 30 minutes


C
N
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4.4.3 - Sensitivity to non-cost-related aspects

This section studies the sensitivity of accessibility changes due to road pricing for two aspects which are not specifically confined to or only important in a road pricing situation: (i) the influence of the contour impedance step for contour measures and the cost-sensitivity parameter for potential measures and (ii) the influence of network detail. The sensitivity to these aspects is only studied on the basis of the kilometre charge measure on all roads. A motivation for this and for conducting specifically these two sensitivity analyses was provided in section 4.1. Section 4.4.3.1 presents the (spatial) sensitivity results to the applied resistance parameter. Section 4.4.3.1 focuses on the sensitivity to network detail.

4.4.3.1 – Sensitivity to impedance step or cost sensitivity parameter

The sensitivity of accessibility outcomes is tested for four contour impedance steps: a cost equivalent of 5, 10, 15 and 30 minutes (see section 4.2.2). Higher mean accessibility decreases are found for higher impedance steps. For an impedance step of (a cost equivalent of) 30 minutes, for example, a person living in an average zone can almost reach 35 percent less of the total jobs in the study area in the situation with road pricing. In the case of an impedance step of 5 minutes this is less than 2 percent. If the contour step is higher, differences possibly become larger, since kilometre costs increase when distances do. And since monetarized travel time gains are lower than losses due to higher kilometre costs, differences in accessibility are higher if the impedance step is larger. Of course a sort of optimum in differences exists. If the impedance step becomes so large that all job opportunities within the research area can be reached from all zones either with or without pricing costs, job accessibility differences are zero.

In addition to using the indicator mentioned above to assess more ‘aggregate’ differences in accessibility, the influence of the impedance step on the spatial accessibility pattern was studied. Absolute accessibility changes per contour impedance step are shown in figure 4.29. Relative changes are given in figure 4.30. Using a cost equivalent of 5 minutes, the highest absolute decrease in accessibility is found in some zones in Eindhoven. There, small travel cost changes may determine whether zones with a high share of jobs in close vicinity can barely or not at all be reached within the impedance step chosen, causing a higher possibility of large (absolute) differences in accessibility compared to rural areas (i.e. with fewer job opportunities reachable only at longer distances). For around 5 percent (i.e. 132 zones) of the zones, located in more rural areas, accessibility does not change. If higher impedance step boundaries are chosen, the highest differences are found further removed from the city. In the case of a cost equivalent of 30 minutes, the highest differences emerge at the fringes of the research area; the smallest decreases can be observed in and around Eindhoven. A possible explanation is that within a cost equivalent of 30 minutes, a large part of job opportunities can be reached from zones that are located in or near to Eindhoven, both with and without a kilometre charge. For zones in the outer parts of the study area differences are still large because starting from these zones the large job pool in the city may not be totally reachable within the chosen impedance step, at least if pricing costs are taken into account. This effect was also observed in section 4.3.2. However, in that section the results were the opposite: accessibility *increases* due to travel time gains.

As was pointed out in section 4.4.1, the spatial image of accessibility change is different when the relative instead of the absolute accessibility change is regarded. The same kind of differences between the relative and absolute accessibility change can be observed for different contour impedance steps: the relative accessibility decreases are relatively low in Eindhoven compared to zones located further away. In the case of a cost equivalent of 5 minutes (see figure 4.30) the zones with the highest accessibility decreases are scattered across the study area and mostly border to (but are not part of) a village or city. When the impedance step increases to cost equivalents of 10 or 15 minutes a more regular picture emerges: the highest accessibility decrease is found for zones that are located in a wide ring around Eindhoven and for zones that are situated at the borders of the research area. An explanation for this spatial pattern was provided in section 4.4.1. For a cost equivalent of 30 minutes differences between the 'relative' and 'absolute' accessibility pictures are once more small. Within a cost equivalent of 30 minutes (a large part of) the job pool in Eindhoven cannot be reached from the zones at the border of the study area when road pricing is considered. This leads to large absolute as well as relative differences at the fringes, resulting in quite comparable accessibility pictures for the absolute as well as the relative change.

For the potential measure three cost sensitivity parameters were used in the analyses: 0.5, 1 and 2. The results are presented in figure 4.31. In general, a higher sensitivity parameter results in a higher influence of travel costs (i.e. a higher cost decay). This leads to higher relative accessibility decreases when the cost sensitivity parameter is higher.

Figure 4.31 shows that, for parameter values of 0.5 and 1, the accessibility change is not very differentiated, due to the classifications we selected to compare the results for different cost-sensitivity parameters. Figure 4.31 indeed shows that accessibility decreases become higher when the cost parameter increases. In the case of using a parameter value of 2 (i.e. a quadratic 'decay' function) the lowest accessibility decreases occur around the places/towns where most jobs are located. The largest differences are to be found in the zones located between the job centres and in the fringes of the study area. Thus, it would appear that a higher parameter not only leads to higher accessibility differences. From a spatial point of view the application of higher parameters leads to more local differences in accessibility.

In conclusion, the spatial sensitivity to the contour impedance step of a contour measure and to the cost-sensitivity factor of a potential measure is high. It is not only the average accessibility (over all zones) that strongly changes, but the spatial pattern of accessibility is highly sensitive to the impedance step (in the case of contour measures) and for the cost sensitivity parameter (for the potential measure) used as well. This would appear to indicate that it is important to take several resistance parameters into account when the aim is to get a valid and complete insight into accessibility changes due to road pricing measures.

4.4.3.2 Sensitivity to network detail

Accessibility changes may be sensitive to changing the network and zoning detail. When the Delauney sub-network is not taken into account, there is a general decrease in resistance between most zones (see also section 4.2.2). The average origin-destination travel time decrease is approximately 7 percent. This average decrease in travel time is likely to lead to an average 7 percent decrease of the generalized transport costs in the situation without road pricing. However, lower origin-destination distances in the situation with road pricing not only have the effect that the monetarized travel time component is lower: average toll costs also decrease. Overall, this may lead to a small decrease of contour based accessibility changes in the case of a less detailed network. Nevertheless, if the contour impedance step is left unchanged (i.e. VOT of

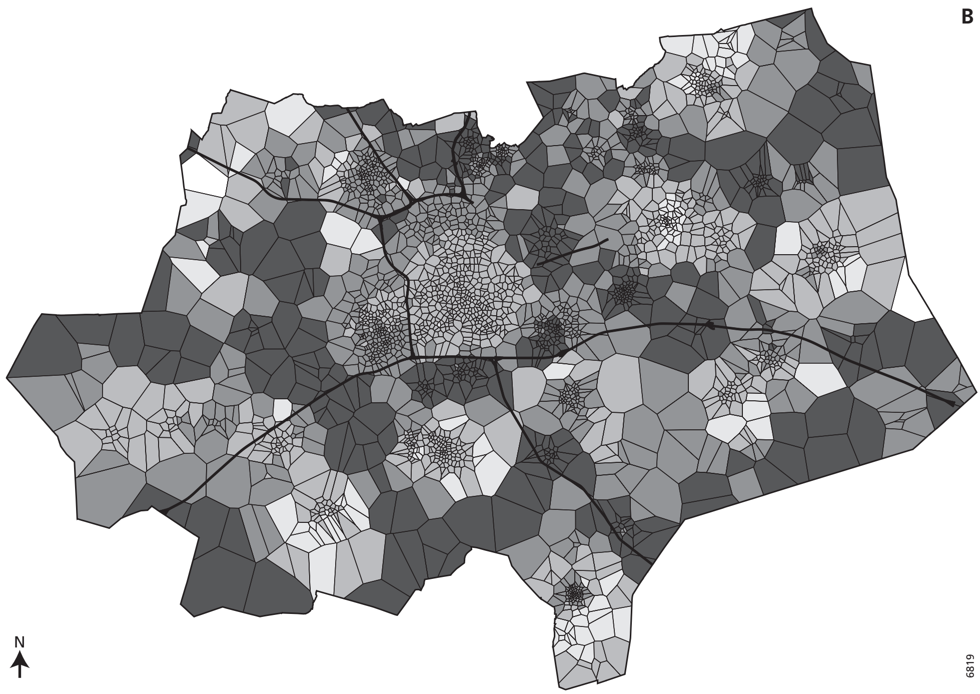
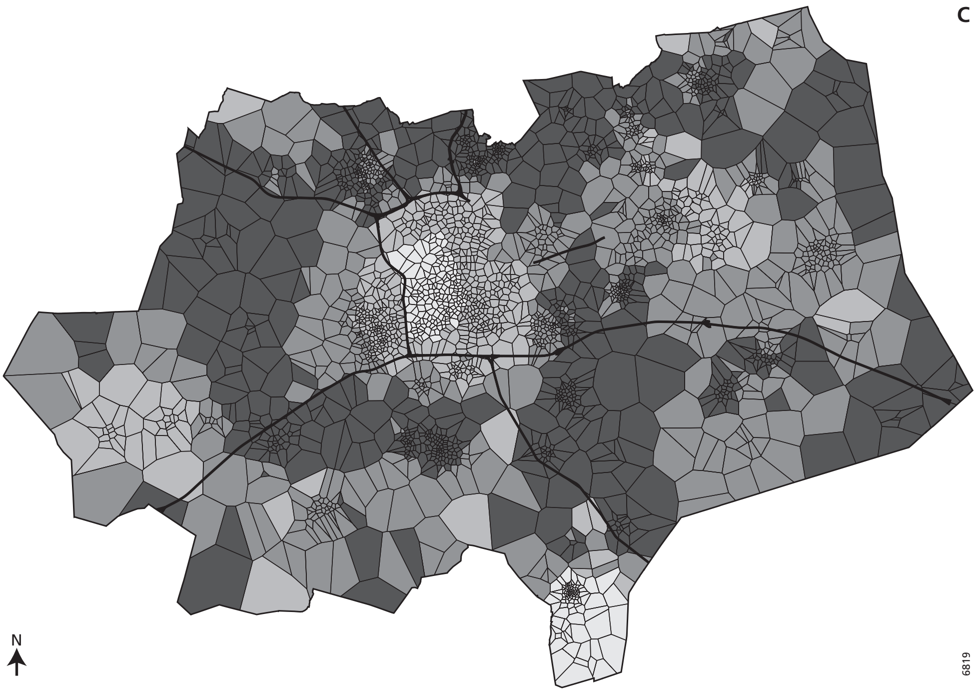
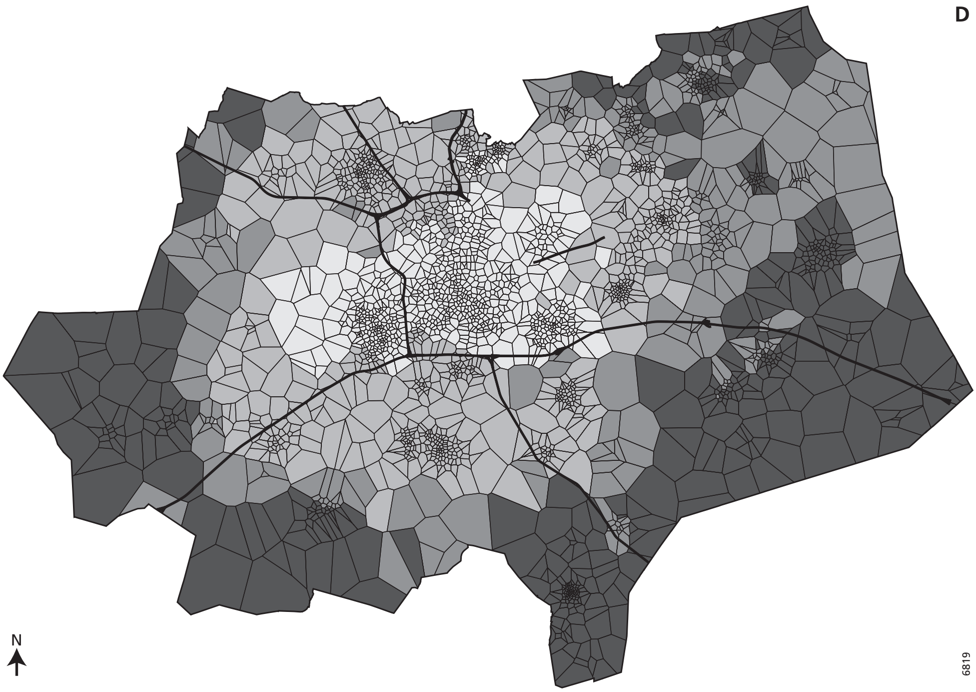


Figure 4.30: relative job accessibility decrease due to kilometre charge on all roads. Contour measure with different (cost equivalent) impedance steps. A: 5 minutes. B: 10 minutes. C: 15 minutes. D: 30 minutes

C



D



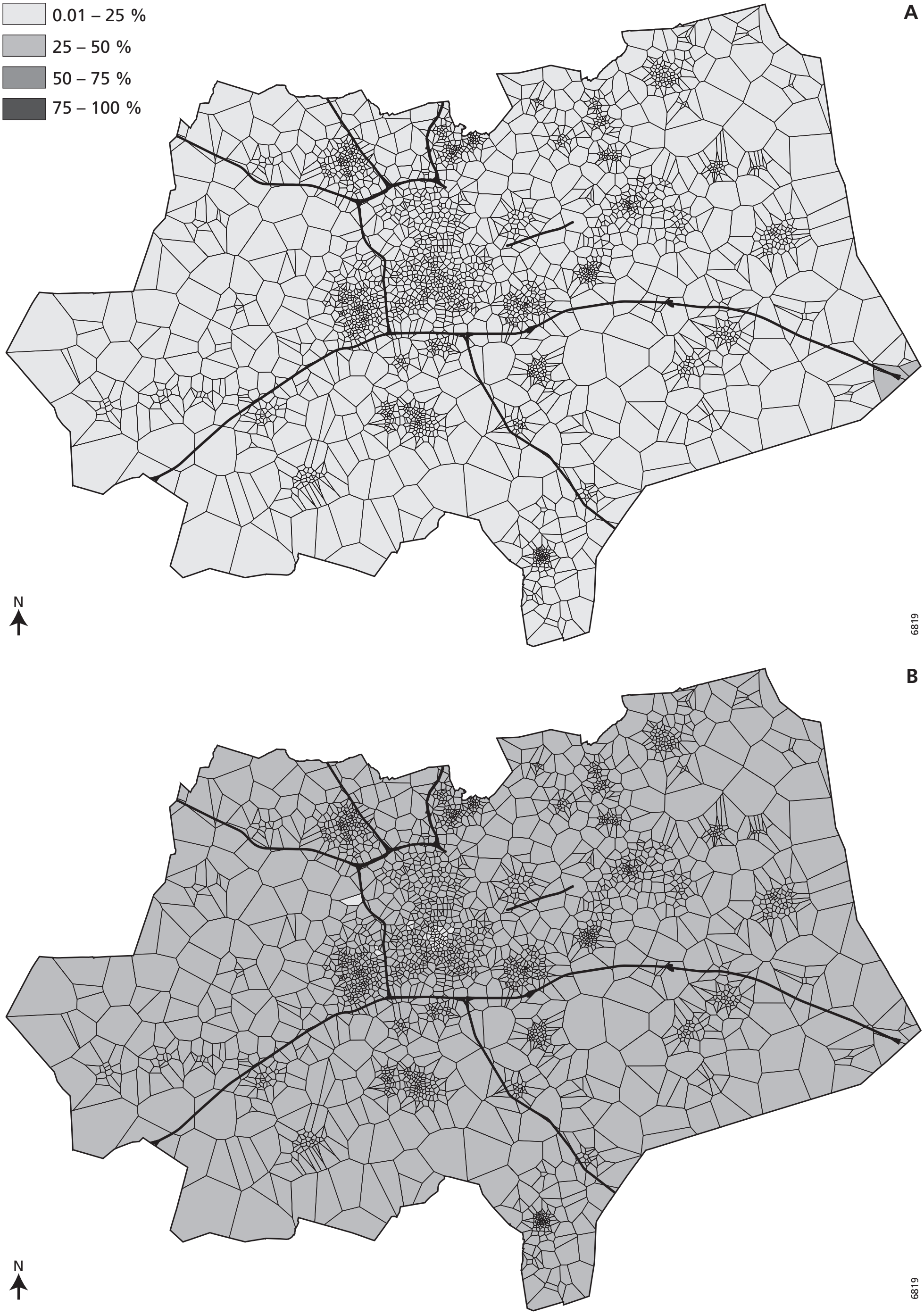


Figure 4.31: relative job accessibility decrease due to kilometre charge on all roads. Potential measure with different cost sensitivity parameters. A: parameter 0.5. B: parameter 1. C: parameter 2

11 euro/hour * 15 minutes), more jobs can be reached when the small network is applied. This in turn may counter[91] the expected lower accessibility change for less detailed networks. Finally, a complicating factor is that for some origin-destination relationships the distance and travel times may be higher for the less detailed network (i.e. without the Delauney sub-network). This occurs when the distance via the Delauney network is shorter than the corresponding distance via the basic network.

Focusing on actual results, the average accessibility decrease for the large network is marginally higher than for the small network. However, differences are small. This was also found in the case of the spatial pattern of accessibility. Although the more detailed zoning system (2819 zones) results in a somewhat more differentiated accessibility pattern, the general image is quite comparable to the spatial pattern derived when using the small network with only 441 zones.

In conclusion, from a sensitivity (of accessibility change) point of view it may not be necessary to increase the level of detail with respect to the road network and the zoning system. The accessibility decrease due to pricing is only slightly lower when the less detailed network and zoning system are used. Moreover, the general image of the spatial pattern of accessibility change does not alter when the network and zoning detail changes. From a geographical 'correctness'

91 The previous section (4.4.3.1) showed that accessibility changes increase when higher impedance steps are used. A lower overall resistance keeping the resistance boundary unchanged is comparable to increasing the impedance step without an overall resistance change. Thus, a general resistance decrease may, in correspondence with the results presented in section 4.4.3.1, also lead to higher accessibility changes.

point of view, however, the use of feed points is less ideal, as in fact people do not live or work at these 'fictitious' locations. Therefore, from a geographical perspective the detailed zoning system is more realistic and leads to a somewhat more spatially differentiated accessibility pattern, as described in section 4.2.2.

4.5 - Conclusions, discussion and recommendations

The aim of this chapter has been to gain greater insight into the sensitivity of job accessibility changes due to (time-differentiated) kilometre charges. Two methodological lines in studying sensitivity were distinguished. In the first one, the sensitivity of accessibility changes due to road pricing was studied for varying aspects that are particularly related to road pricing conditions. Examples of such aspects are: the price measure (i.e. type of price measure, price level and trip demand elasticity), the height of the value of time and the (number of) factors taken into account in the impedance function. With respect to the second methodological line the sensitivity under road pricing conditions was studied for varying characteristics, which may not only be important to take into account in studying the sensitivity of accessibility changes due to road pricing, but which may also affect the sensitivity of accessibility outcomes in all kinds of studies. In this chapter the sensitivity analyses that were conducted for the type of accessibility measure, the analyses for the resistance parameter or impedance step used and the sensitivity analyses for the level of network and zoning detail can be assigned to this second methodological path.

On the basis of the sensitivity analyses it can be concluded that accessibility is sensitive to varying cost aspects. The sensitivity of accessibility changes was tested for two types of pricing measures: a time-differentiated kilometre charge on all roads and a time-differentiated kilometre charge on motorways. The spatially differentiated kilometre charge (i.e. on motorways) leads to more 'preferred' effects than the kilometre charge raised on all roads: accessibility losses due to pricing are lower and/or gains are higher. A spatially differentiated kilometre charge results in somewhat higher time gains, because this measures is implemented particularly on locations in the study area where traffic congestion problems are most severe (in this case the motorways). Additionally, people on the lower-scale road network do not have to pay charging costs. In combination the higher travel time gains and lower overall charging costs result in a lower accessibility decrease (or higher increase) due to the spatially differentiated kilometre charge. Nevertheless, although the spatially differentiated charge scores 'better', time gains alone on average do not compensate for the (extra) monetary costs of the pricing measure(s), as was expected on the basis of the economic welfare theory.

The fact that a more differentiated kilometre charge is more effective in reducing congestion problems merely confirms the general expectation (see, for example, May and Milne, 2000). The innovative aspects of this study are, however, that effects were assessed by means of a state-of-the-art traffic assignment model that is able to cope with, for example, departure time changes, elastic demand and blocking back effects of traffic queues. Furthermore, not only travel time gains were incorporated into the analyses, but the influence of the monetary charging cost component was examined as well. This has the effect that locations that profit from travel time gains do not necessarily experience an accessibility gain since travel costs also increase. A final added value is that the applied procedure makes it possible to study spatial differences in accessibility change due to different pricing measures: e.g. it allows us to see which zones (where people live) benefit to a greater or lesser extent from a particular pricing measure.

Moreover, the sensitivity of accessibility outcomes for assuming elastic or inelastic trip demand due to pricing was examined. In the case of elastic trip demand fewer people will undertake a trip because of the charge. This results in (extra) travel time gains. The sensitivity to the assumption of (in)elastic demand was found to be high only for the spatially differentiated kilometre charge. With respect to the kilometre charge on all roads, by contrast, extra travel time gains due to the assumption of elastic trip demand are more strongly outweighed by the charging costs, resulting in a low sensitivity to (in)elastic trip demand. Subsequently, the sensitivity of accessibility measures for price level variations was studied for the kilometre charge measure on all roads (see section 4.1 for a motivation). With respect to varying the charge level we found that higher monetarized travel time gains alone (without rebates) are not big enough to compensate for the extra costs incurred by higher charge levels. This results in higher accessibility decreases for higher charge levels. There will be an optimum toll level. However, because this study focused on 'sensitivity', we did not aim at finding that optimum charge level.

In addition to studying the sensitivity of accessibility outcomes to price measure-related characteristics, we also studied the sensitivity to varying aspects in the generalized transport cost function. The sensitivity of accessibility changes for varying the VOT is comparable to changing the charge level. Due to a change in VOT the relative influence of the monetarized travel time component in the generalized transport cost function changes. It is especially this effect that causes the overall sensitivity of accessibility changes. Furthermore, 'trade-off' values of time for which the same share of zones in the research area show an accessibility increase or decrease due to road pricing were computed. The kilometre charge on all roads resulted in a trade-off value of 1250 euro/hour when trip demand was assumed to be inelastic. For elastic demand this value decreased to approximately 250 euro/hour. For the spatially differentiated charge values of 100 euro/hour for inelastic and 20 euro/hour for elastic trip demand were found. This latter value of 20 euro/hour already comes close to 'realistic' average values of time for car commuters (e.g. time-pressured commuters, business travellers).

The influence of adding a fuel cost component or including a revenue use component to the generalized transport cost function was tested as well. Although the results seem to be very sensitive to adding an extra cost component to the cost function, in fact this is rather a 'fake' sensitivity, since the extra fuel cost component is added both for the situation with and without the charge, causing differences in resistance between both situations to remain the same. Subsequently, the sensitivity to the revenue use component was found to be quite high, because kilometre costs were reduced with 3.4 cents/kilometre. The 'type' of sensitivity is not different than the sensitivity to changing charge levels. Nevertheless, accessibility in general decreases for the reference situation even if the rebate is taken into account.

In addition, the sensitivity was studied for the type of accessibility measures, the resistance parameter used (i.e. impedance step in the case of a contour measure and the cost sensitivity parameter for a potential measure) and the level of zoning and network detail. Two types of accessibility measures were used in the analysis: contour and potential measures. Both measures in general show quite comparable outcomes when the results are averaged over all zones. Nevertheless, focusing on the spatial pattern of accessibility changes due to pricing (i.e. which zones loose or gain to what extent), the sensitivity to the type of accessibility measure is large, as is the sensitivity to the representation of accessibility change: relative or absolute accessibility change. Additionally, the spatial sensitivity to the selected contour impedance step and for the cost sensitivity factor of a potential measure is also high, i.e. not only the average accessibility (over all zones) strongly changes. Also, the spatial pattern of accessibility is highly sensitive to the resistance factor used. In fact, this resistance parameter mainly determines the spatial sensitivity of accessibility. Changes in cost aspects on the other hand merely lead to more or less strong accessibility changes within the 'spatial accessibility pattern' determined by the resistance parameters used. Moreover, the sensitivity of accessibility changes for the network and zoning detail was not found to be high: the general image of the spatial pattern of accessibility change does not alter when the network and zoning detail changes. From the point of view of geographical 'correctness', however, the use of feed points is less ideal, because in fact people do not live or work at these 'fictive' locations. Also, if one wants to focus on more disaggregate analysis levels, a more spatially differentiated zoning system is preferred.

On the basis of the reported sensitivity results some general recommendations can be given for actually modelling the accessibility effects due to road pricing. The results indicated that the sensitivity to several cost aspects is high. This supposes, for example, that it may be important to differentiate the VOT in the generalized transport cost function when one wants to compute realistic geographical accessibility effects due to road pricing measures. A differentiation towards some important VOT-influencing factors, such as income, may already improve realism of accessibility outcomes substantially. Beside the sensitivity to the value of time, accessibility changes were shown to be sensitive to the charge level that was selected. Higher charge levels resulted in higher accessibility losses (for the charge on all roads). It may, therefore, be recommendable to evaluate the accessibility effects for different price levels before actually implementing a price measure. In that way an optimal charge level can be found. Apart from the value of time and charge level analyses, accessibility effects were modelled both for assuming elastic and inelastic trip demand. For the spatially differentiated charge results were observed to be sensitive to assuming inelastic or elastic demand. It thus seems to be important to incorporate demand elasticity in modelling accessibility effects due to pricing not only because accessibility effects are sensitive to elastic demand, but also because assuming inelastic demand is quite unrealistic: in reality some people are expected to decrease their trip frequency due to pricing measures. Moreover, if the aim would be to use accessibility measures to compute 'realistic' accessibility effects due to road pricing, important benefit components such as a rebate coefficient must be taken into account. It would then be good not to use one general rebate coefficient like we did in this chapter, but to differentiate according to groups of people (e.g. different weight classes of cars if revenues are used to abolish fixed annual car taxes according to the weight of the car). In addition, differentiation of fuel costs towards for example the fuel type and fuel consumption of the car may make the results more realistic.

Also, some recommendations can be given with respect to accessibility modelling issues that are not particularly 'cost'-related. The observed sensitivity to the type of accessibility measure implies that it is advisable not to stick to only one type of measure when spatial changes in accessibility due to road pricing have to be simulated. Subsequently, the observed (spatial) sensitivity to the resistance parameter of contour and potential measures indicates that it may be important to take more resistance parameters into account when the aim is to gain a valid and complete insight into accessibility changes due to road pricing measures. Finally, the sensitivity to network detail was found to be rather low. But instead of using feed points, which in fact are imaginary points, it is advisable to use a study area configuration in which the origin and destination locations represent 'real' locations. The advantage of using smaller zones is that it is possible to compute more spatially differentiated accessibility effects.

As indicated in chapter 2.5.3.3, 'objectively' computed accessibility changes due to a pricing measure (e.g. with financial travel time gains and charging costs) may be different from how people actually perceive changes in accessibility. In a stated preference questionnaire people were asked to indicate whether they thought they would be better or worse off due to a kilometre charge. These questions may be used as a proxy for perceived accessibility change. The respondents were presented a kilometre charge with a corresponding travel time gain due to the charge. These price-time combinations were systematically varied around a persons' individual value of time (which we knew from another questionnaire). This means that, for example, the travel time gain that was being presented was equal to what respondents would demand on the basis of their VOT, given a certain road pricing cost. Travel time gains and charge levels were varied according to three VOT-proportions: 0.75, 1 and 1.5*VOT. A more detailed description of this experiment and the analysis results are given in Appendix D. The results indicate that car commuters seem to be rather insensitive to travel time gains. It would appear that a large share of the respondents who have a certain perception regarding road pricing impacts stick to that perception or at least are not easily influenced by travel time gains.

It would appear that the need to put much effort in differentiating the VOT depends on what it is one wants to model. To model 'objective' accessibility effects due to road pricing it makes sense to use some differentiation in the VOT, as accessibility changes are sensitive to the VOT. However, peoples' perceptions with regard to being better or worse off due to kilometre charges (causing time gains) are very insensitive to the time gain produced by a charge. Being a little bit cautious this may also mean that it could be more worthwhile to gain insight into socio-economic and demographic factors that explain the differences between people's perceptions as to whether they are better or worse off, than to put a great deal of effort into differentiating the cost function towards different values of time. This information can then be used to update the resistance component of accessibility measures if the aim is to decrease a possible existing discrepancy between more objectively measured and perceived accessibility. How to include such a perception component is a topic for further research.

The sensitivity of accessibility outcomes was studied on the basis of a regional study area around the city of Eindhoven. The average accessibility changes due to road pricing seem to be rather robust for a given study area, at least when research areas with (average) congestion problems are regarded. However, this is not the case for the spatial pattern of accessibility. The 'spatial pattern' of results is largely influenced by the presence of Eindhoven, because (i) a large share of the jobs is available in and around this city and (ii) (somewhat related) the density of the network is and the traffic congestion problems are highest in Eindhoven. The 'spatial' sensitivity as a consequence may be very much dependent on the type and location of the study area.

In this chapter we have looked at some of the relevant accessibility modelling issues. In the next three chapters we focus on the extent to which people and firms intend to change their behaviour as a result of different pricing measures. In chapter 5 we analyze changes in the short-term trip pattern of households due to road pricing measures.

5 - Road pricing and changes in the trip behaviour of households

5.1 - Introduction

Whereas chapter 4 was a methodological chapter primarily concerned with the sensitivity of modelling the (accessibility) effects of road pricing measures ex ante, this chapter forms the first chapter in this thesis in which (possible) behavioural effects due to road pricing are studied on the basis of empirical research. This chapter specifically focuses on studying short-term behavioural (i.e. trip change) effects due to different pricing measures, thereby addressing the first part of research question 3 which is printed below. Subsequently, chapter 6 will aim on answering the second part of the research question (i.e. the long-term behavioural effects).

To what extent do (road) pricing policies influence short-term trip/travel patterns *and (re)location, especially work and residential location, choices* **of households?**

To be more precise, this chapter provides insight into the extent to which people intend to make changes in their trip pattern due to pricing measures regarding four trip motives: commuting, social (visiting), other and shopping. Trip changes with respect to commuting, visiting and other purposes are studied on the basis of one dataset (household questionnaire 2); shopping trip changes are retrieved from another dataset (household questionnaire 3). Several aspects regarding trip change behaviour due to pricing measures are studied. Firstly, the number and percentage of car trips that people say they will change due to pricing measures. Secondly, we discuss the alternatives people choose for the car trips they intend to adjust. Thirdly, we explore the differences in the intended trip changes between the various price measures, price levels and types of revenue use. Finally, we examine explanatory socio-economic, demographic and trip-related variables for car trip changes due to pricing.

The outline of this chapter is as follows. Section 5.2 describes the main characteristics of the two datasets we used to study the trip behavioural changes. Section 5.3 focuses on short-term trip changes. In the subsections, the results are described for each of the four trip motives. Furthermore, the subsections of section 5.3 also study the influence of the charge level and the type of revenue use on car trip changes. Section 5.4 aims at an analysis of explanatory factors for changing car trips. The focus lies on socio-economic, demographic and trip related characteristics. The conclusions are presented in section 5.5.

5.2 - Data characteristics

Changes in people's travel behaviour due to transport pricing measures are analyzed on the basis of two datasets. One dataset, i.e. household questionnaire 2, is used to gain insight into short-term changes with respect to the following three trip motives: commuting, social (visit) and other motives. Another dataset, household questionnaire 3, provides insight into changes regarding daily and non-daily shopping trips. Chapter 3 described the general characteristics of the various questionnaires that were conducted within the MD-PIT[92] project. Section 3.4.4 concentrated on the characteristics of household questionnaire 2, while section 3.4.5 focused on household survey 3. However, chapter 3 aimed at providing a general insight into (all) the topics (not only short-term behavioural changes) that were included in the questionnaires. This section extends the content of chapter 3 by describing in greater detail the questions related specifically to the short-term behavioural changes of households. Moreover, for the reader's convenience some important characteristics that were already described in chapter 3 are repeated.

The dataset of household questionnaire 2 consists of 562 respondents, 288 of whom are commuters who drive to work by car twice or more per week and face congestion of 10 or more minutes per trip at least twice a week. The rest of the respondents were selected only on the basis of owning a car (i.e. within the household). Car commuters facing congestion problems were chosen, because it is in particular these types of commuters who will be confronted with price measures aimed at reducing congestion. In addition, making sure we interviewed people owing a car allowed us to study short-term effects for other groups of people as well, for example people who do not work or do not (always) use their car for the commute trip.

Three kilometre charges were presented to each respondent (see Table 5.1): (i) a flat kilometre charge, (ii-a) a combined kilometre and peak charge or (ii-b) a kilometre charge differentiated with respect to the weight of the car and (iii) finally a time-dependent kilometre charge. The first and third kilometre charge consisted of six variants (i.e. three price levels, two types of revenue use); kilometre charge 2 contained two alternative charges. From each of the three kilometre charge categories one variant was randomly selected and presented to the respondent. Respondents in principle indicated the intended changes in their short-term trip pattern for three motives: commuting, social (visit) and a rest category (called all other motives). The term 'in principle' in this respect means that respondents only reported changes for a certain trip motive if they currently made at least one car trip each week for the purpose in question.

One of the reasons why we selected these trip purposes was already discussed in chapter 3. To resume, we selected commuting because commuters are a group of people who are likely to face congestion on a regular basis; the social ('visiting') purpose was selected because this is a purpose most people recognise and find it easy to imagine; and to be able to present a complete picture of all changes the respondents intend to make in response to transport pricing measures we also added the trip motive 'other' (see also section 3.4.4).

With respect to the trip change questions, a hierarchical approach was applied. After the presentation of each price measure the respondents were asked first whether or not they intended to make any changes in their commuting behaviour. They could choose three options: to change nothing, to make more commuting car trips or to make changes in their current commuting trips by car. Respondents who indicated they would change nothing we asked no other questions regarding short-term commuting. People that wanted to make more trips were also asked to

92 This is short for 'a Multi-Disciplinary study of Pricing policies In Transport' (see also section 1.1 or Appendix A).

Table 5.1: different kilometre pricing measures and variants within household questionnaire 2

Measure	Alternative
1. km charge (flat)	A: 3 € cent, abolishment of car ownership taxes B: 6 € cent, abolishment existing car taxation (purchase and ownership) C: 12 € cent, abolishment existing car taxation and building new roads D: 3 € cent, revenues used for lowering income taxes E: 6 € cent, revenues used for lowering income taxes F: 12 € cent, revenues used for lowering income taxes
2. km charge	A: 2 € cent with a morning and evening peak time charge (time dependent and stepwise), revenues used for abolishment of existing car taxation B: differentiated according to weight of the car, revenues used to abolish existing car taxation (4, 6, 8 € cent for respectively light, medium weight and heavy cars)
3. km charge (time-differentiated)	A: 2 € cent outside and 6 € cent within peak periods, abolishment of car ownership taxes B: 4 € cent outside and 12 € cent within peak periods, abolishment existing car taxation C: 8 € cent outside and 24 € cent within peak periods, abolishment existing car taxation and building new roads D: 2 € cent outside and 6 € cent within peak periods, revenues used for lowering income taxes E: 4 € cent outside and 12 € cent within peak periods, revenues used for lowering income taxes F: 8 € cent outside and 24 € cent within peak periods, revenues used for lowering income taxes

indicate how many more commuting trips they would make on a weekly basis. Respondents who selected the final option were asked how many of their current car trips they wanted to adjust in a four week period[93]. Subsequently, they had to divide these adapted trips among several alternatives: public transport, slow traffic, other motorized traffic (owned by the respondent), carpool, travel at other times, work at home and not making the trip. Respondents could not divide more trips than they intended to change. Moreover, the option of 'travel at other times' could only be selected if a time-differentiated charge was presented (i.e. measures 2A and 3).

In the case of the other two trip motives (visiting and other) basically the same procedure was followed. The only difference relates to the first question. Respondents could not choose to undertake more trips with respect to visiting or other trips. The reason for this choice is merely that it was regarded as rather unlikely that people would undertake more of these trips due to pricing. And, because of budget reasons every opportunity was used to keep the questionnaire length within reasonable limits.

The advantage of using one rest category defined as 'other motives' is that, in combination with the commute and visit purposes, a complete picture of behavioural changes can be derived. Assuming there were no budgetary restraints it would have been ideal if we could have studied people's behavioural changes for a whole/wider range of concrete trip motives. Within this

93 The four week time span was used to assure a reasonably high number of trips such that the division of the to be adapted trips among various alternatives can be made more easily than would be the case if we were to use a weekly framework.

chapter short-term trip changes are also analyzed for daily and non-daily shopping trips[94], on the basis of another dataset collected by students: household questionnaire 3 (see section also 3.4.5). The cleaned-up dataset of this questionnaire consists of 266 respondents that use their car at least once a week for daily shopping purposes or at least once a year for non-daily shopping in another city (than where they reside). The questionnaire consisted of four versions, each containing one time-differentiated[95] price measure (see Table 5.2): a low kilometre charge (74 respondents) and a high kilometre charge (66 respondents) and a low and a high cordon charge (respectively 59 and 67 respondents). Every respondent was assigned only one of the four versions. Kilometre charges were used to compare behavioural changes in shopping trips (i.e. questionnaire 3) with intended trip changes for social and for the combined category 'other' purposes. Because questionnaire 3 was carried out earlier than questionnaire 2, and because questionnaire 2 was part of a multidisciplinary data collection in which the partners within the MD-PIT project had to agree about the contents, price levels in questionnaire 3 are somewhat different than in questionnaire 2. Cordon charges were taken into account in questionnaire 3 because cordon charges may lead to quite different behavioural effects. The threshold to pass such a cordon with a relatively high charge on a fixed point may be high, which may lead to other behavioural effects than if a kilometre charge is applied. Furthermore, the decision to use varying price levels for the two measures was made to allow us to study the effects of price height on people's behaviour.

Each questionnaire contained questions concerning trip changes with respect to daily and non-daily shopping trips. Daily shopping was defined as daily grocery shopping such as buying food or care products at the supermarket. Non-daily shopping was defined as shopping in another city, for instance recreational shopping. Searching and buying 'non-daily' goods such as clothes, furniture, jewelleries etcetera were also considered non-daily shopping in another city. Again, a hierarchical approach was used. Respondents were first asked if they wanted to change their daily shopping behaviour. They could either choose not to change anything or to change their current behaviour with regard to daily shopping. The option 'more car trips for shopping' was not available, because, as was the case with the categories 'visiting and other' in household questionnaire 2, the probability of occurence was assumed to be low. People who indicated they wanted to adjust their current shopping car trips were asked to determine how many trips they would change on a weekly basis. These trips in turn had to be divided among several options: public transport, other (slow) transport, travel at other times, combining trips, change the shopping location and not making the trip anymore. Although we followed this hierarchical procedure both for the kilometre and for the cordon charge questionnaire versions, there was also a clear difference with regard to the type of measure. The cordon charges were only assumed to be implemented around the four largest cities in The Netherlands: Amsterdam, Rotterdam, The Hague and Utrecht. Therefore, questions regarding the category shopping trips were aimed specifically at trips people make to (one of) these four cities. In the case of the kilometre charge, the daily-shopping traffic was not linked to a certain city and thus, in contrast to the cordon charge, all shopping tips by car were in principle included. This results in higher response rates for the kilometre charge and probably more reliable outcomes with respect to daily shopping,

94 Shopping trips were chosen because they occur regularly compared to many other non-commuting trips. The expectation, therefore, was that respondents would be able to imagine what they might want to change with regard to this specific trip purpose.

95 The peak charge is twice as high as the off-peak charge.

Table 5.2: different time-differentiated pricing measures and variants within household questionnaire 3

Measure	Alternative
1. km charge	A: peak periods (7-9 and 17-19 hr) 10 € cent/km; outside peak + weekend 5 € cent/km B: peak periods (7-9 and 17-19 hr) 20 € cent/km; outside peak + weekend 10 € cent/km *Revenues go to the government and are used for all kinds of things such as education, health care, financing of deficits etcetera.*
2. cordon charge four major cities in the Netherlands (Amsterdam, Rotterdam, The Hague, Utrecht)	A: peak periods (7-9 and 17-19 hr) 8 €/passage (only city inwards); outside peak + weekend 4 € B: peak periods (7-9 and 17-19 hr) 12 €/passage (only city inwards); outside peak + weekend 6 € *Revenues go to the government and are used for all kinds of things such as education, health care, financing of deficits etcetera.*

because we expected that in most cases people make their daily shopping trips in the town where they live (assuming that there are supermarkets).

Non-daily shopping was defined as non-daily shopping in another city. An important reason for using this definition is that this ensures that distances are high enough for the kilometre charge to have an impact. For the questionnaires that included the cordon charge this other city had to be one of the four major cities in The Netherlands; for the 'kilometre charge' questionnaires it could be any other city. With respect to changes in the non-daily shopping pattern by car the same hierarchical procedure was used as for daily shopping. However, there are some small differences. First of all, the time unit of measurement was different. Non-daily shopping occurs less frequently than daily shopping. Therefore, whereas a one week period was used for reporting daily shopping trip changes, a one year time span was used for non-daily shopping. Another difference has to do with the alternative trip options that were available. For non-daily shopping in another city, people could not choose the options 'other motorized (own) transport' and 'combining trips'. The expectation was that people rarely do their non-daily shopping alone. Thus, the likelihood of people using other kinds of motorized transportation (for instance a motorbike) is quite low. Moreover, combining several trips to make the total trip pattern more efficient is not seen as a realistic option for non-daily shopping. The decision to remove these two categories ex ante was primarily made to reduce the complexity (and length) of the questionnaires as much as possible.

5.3 - Short-term behavioural intentions and the influence of price measure characteristics

5.3.1 - Introduction and applied methodology

This section describes the short-term behavioural (trip) changes that respondents intend to make due to different transport pricing measures. Each subsection focuses on one trip purpose. Trip changes regarding commuting are presented in section 5.3.2. Results for the motives social (visiting), other and shopping are presented in sections 5.3.3 to 5.3.5 respectively. Within sections 5.3.2 to 5.3.5 results are described first in an overview of the changes people intend to make (i.e.

number/percentage of car trip changes and the alternatives chosen). Subsequently, differences between the results for different price measures, price levels and types of revenue use are analyzed. Analyzing the influence and differences in effects of the various price measures, price levels and types of revenue use may help actors, such as policy-makers in finding 'appropriate' specifications of pricing measures.

As described in section 5.2, the price measures in household questionnaire 2 consisted of different alternatives. The first and third kilometre charge comprised six alternatives (i.e. three price levels, two types of revenue use) and the second kilometre charge contained two alternative charges. Within each of the three kilometre charge categories, one alternative was randomly selected and shown to the respondent. In principle one may expect a higher price level (in the case of measures 1 and 3, where price level is varied) to lead to a higher degree of adjustment of people's current travel behaviour. However, for budgetary reasons and to keep the size of the questionnaire within acceptable limits we presented only one (randomly selected) price level per road pricing measure to each respondent. This implies that for each price measure the effect of price level can only be studied on an 'inter-personal' level rather than on an 'intra-personal level'. For large datasets this may not be a big problem because the different alternatives often reoccur and are shown to a varied group of respondents with different trip characteristics. However, even then a higher price level does not necessarily have to lead to higher overall costs than in the case of a lower price level. People who drive more kilometres may have to pay higher overall trip costs in the case of a lower price level compared to people who drive less but have to pay a higher price per kilometre. Thus the sensitivity to the height of the charge (per kilometre) may be slightly distorted by the number of kilometres driven by car[96]. Therefore, studying the influence (on trip change behaviour) of trip costs that are operationalized differently may be interesting too. In addition to the price level of the charges, personal overall annual toll costs[97] were also shown to each respondent within the price measure description. This annual toll cost variable fixes the problem mentioned before: in contrast to price level, higher annual toll costs actually imply that someone has to pay more per year. Nevertheless, someone who is confronted with a higher annual toll does not necessarily have to be worse off in a monetary sense than someone who has to pay a lower toll cost fee. Depending on the type of revenue usage overall trip costs (toll costs – monetary rebates) may be different. For example, one type of revenue use that was presented to respondents was a (partial) abolition of existing car taxes (purchase and ownership). The ownership tax implies that someone who has a heavier car has to pay higher (annual) ownership taxes. Moreover, diesel car drivers have to pay a higher (annual) tax than petrol drivers. When all costs and rebates are taken into account this may result in a car driver who has to pay higher toll costs than another person in the end actually having to pay less due to the use of revenues. Within each price measure all three 'cost' variables were given: the price level, the annual toll costs and the annual trip costs (i.e. annual toll costs – revenues). Apart from the question whether the height of trip costs actually influences the travel behaviour, the methodological aspect of which type of cost operationalization (price level, annual toll costs or overall costs) is most explanatory for behavioural changes may be interesting.

96 This 'distortion' can, of course, be controlled for in multivariate analyses, e.g. by including distance.

97 These annual toll costs are derived by multiplying the price level per kilometre with the annual number of kilometres driven by a respondent. If the charge consisted not only of a price per kilometre but also included a charge for passing a toll point, the expected number of 'toll-point crossings' was multiplied by the height of the toll charge.

Therefore, the choice is made to study (where possible) the influence of the height of three types of cost variables: price level, annual toll costs and the overall annual costs or benefits.

Figure 5.1 gives a detailed schematization of the analyses that were carried out. Price measures 1 and 3 are quite comparable with respect to how the measures are constructed and presented to the respondents. Both measures 1 and 3 consist of six alternatives (three price levels and two types of revenue use). The only difference between the measures is that measure 1 represents a flat kilometre charge (i.e. one price level) whereas measure 3 is a time-dependent kilometre charge (i.e. a higher charge inside the peak period than at other times). For price measures 1 and 3, the influence of toll costs and revenue use on car trip change was tested first for the full dataset. Two price variables were analyzed: the price level and the annual toll costs. To test the influence of annual toll costs, two dummy variables were created: higher or lower toll costs than the (i) mean or (ii) median value. Both operationalizations were used because no indication can be given in advance whether a classification on the basis of the mean or median value leads to a higher explanatory power. To keep the complexity and interpretability of analysis within reasonable limits only two classes were chosen.

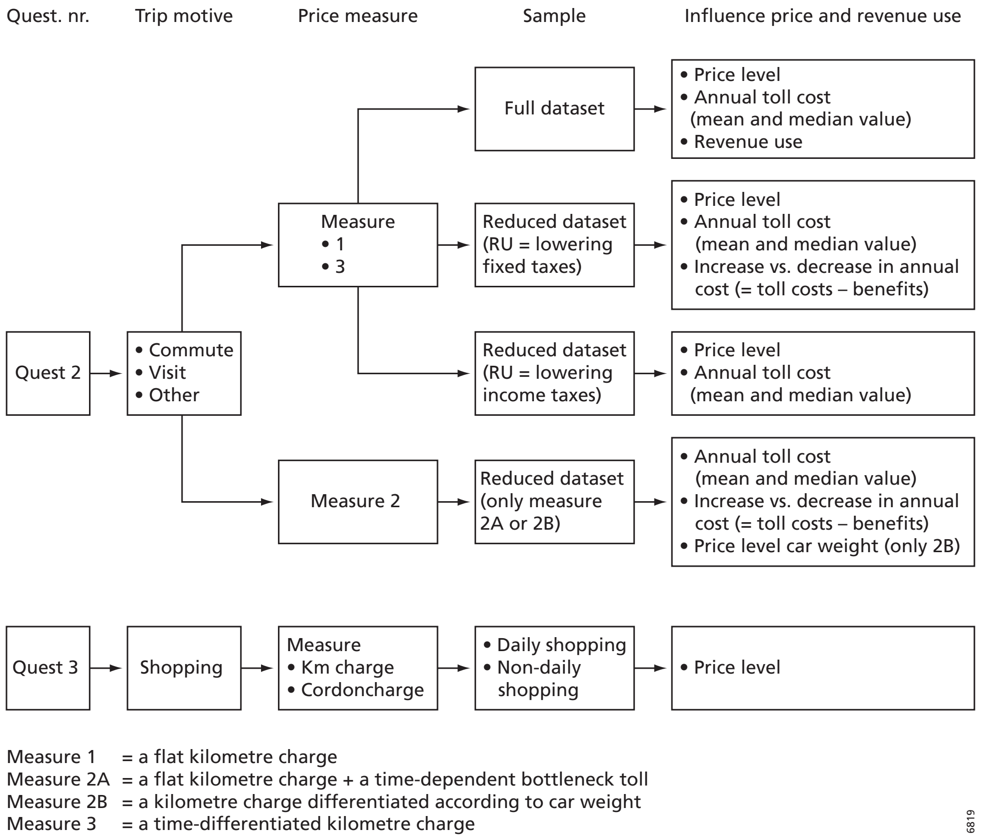


Figure 5.1: schematized overview of standard analyses that are conducted with respect to the influence of toll price and revenue use on the trip change intention

An advantage of using the full dataset (see above) is that the sample is large making it possible to detect small but significant differences. An important disadvantage is that price effects may get blurred by the compensating effect of revenue use, at least as long as one does not control for the type of revenue use. In this chapter we decided also to study the influence of price height for two sub-samples: one sample containing only measures with 'lowering of income taxes' and the other sample only containing 'abolition or lowering fixed car taxes' as type of revenue use. Benefits due to the revenue use 'abolition or lowering existing car taxes' were described to respondents in more detail compared to the general 'lowering of income taxes'. In the case of the first type of revenue use, annual benefits (expressed in costs) were presented within the price measure. The concept 'lowering income taxes', on the other hand, was not operationalized into costs[98]. This means that for the first type of revenue use, overall cost consequences of the measure can be computed as well: annual toll costs minus annual benefits. In total, the influence of three cost variables was tested for the sub-sample containing a reduction of fixed taxes: price level, annual costs and the variable 'increase or decrease of annual costs'. For the other sub-sample we analyzed only the effect of price level and annual costs.

Price measure 2 consists of two alternatives (see Table 5.1). Measure 2A is a fixed kilometre charge with an additional time-dependent toll charge at bottlenecks. Measure 2B is a kilometre charge differentiated according to car weight. Both measures in principle contained the same type of revenue use: lowering fixed car taxes. The toll costs in the case of measure 2A depend on the number of annual kilometres driven (i.e. kilometre charge * number of kilometres per year) and on the number of times (and the time period itself) bottlenecks are passed during a year. Thus, no random price levels were assigned to respondents, as was done for price measures 1 and 3. Therefore, only two cost variables were tested with respect to measure 2A: the annual toll costs (mean and median value) and a dummy variable indicating an overall increase or decrease in annual travel costs. For measure 2B three weight classes were distinguished. Each class corresponded to a certain price per kilometre. It follows that the influence of the cost level for measure 2B can be tested for three cost aspects: the price level (i.e. weight of the car), the annual toll costs (mean and median value) and a dummy variable indicating an overall increase or decrease in annual travel costs.

With respect to the dependent variable in all analyses two configurations were used. The first variable is defined as 'the absolute number of car trips changed'. In the second variable, the absolute number of trips to be adjusted (with a certain motive) is related to the current number of car trips made (with that motive); this leads to a dependent variable 'car trip change relative to the current trips'. Relative changes may be the most interesting subject to study, especially when the results are analyzed at an individual level. For example, the impact of road pricing for people who decide to make one less car trip per week, while making two car trips per week before the pricing measure was implemented, is larger than a change of 5 car trips per week for people who make 20 car trips per week. However, from a methodological point it is also interesting to examine the differences between both types of dependent variables.

98 Reductions in income taxes were not operationalized into concrete cost rebates, because of the difficulty of giving exact personalized indications of effects of lowering income taxes.

To analyze the influence of 'price' on the trip change behaviour, we used t-tests and one-way Anova analyses. Both statistical techniques need a dependent variable measured at an interval or ratio scale. In this case the dependent variables are ratio variables. T-tests were used whenever two 'cost groups' were distinguished (e.g. higher or lower than the mean annual toll costs). In cases where there were more than two classes, Anova analyses were used (e.g. three price levels). As will be shown below, a majority of the respondents do not intend to change anything regarding their current trip pattern by car. In the dataset no change is indicated by a zero value. This means that the dependent variable contains many zero values and in fact is censored to be equal or larger than zero. These large numbers of zeros cause the mean trip change values to become small compared to the standard deviations (in trip change). However, because the dataset is relatively large, even small differences in the mean (in combination with high standard deviations) may become significant. The choice to retain the 'zero-values' in the dependent variable was made because, from a conceptual point of view, 'no change' responses obtained for different (even high) price levels contain information as well. In general, the choice was made to present results that are significant with a reliability of at least 90 percent. The standard level used is significance with a reliability of 95 percent. Whenever results are reported to be significant, without explicitly indicating what the reliability level is, 95 percent is meant. In describing the results we basically used three 'reliability levels', which is in line with what is often found in literature: 90 percent, 95 percent and 99 percent.

In advance of the more detailed description presented in sections 5.3.2 to 5.3.5, we can say that the influence of the height of the price on trip change behaviour is often not significant[99]. The question arose whether that was because we had also taken the 'no change' responses (i.e. zero values) into account in the analysis, which may have led to small differences in the mean values of (the absolute or relative) trip adjustments. Therefore, the choice was made to apply some sensitivity analyses, which are described in section 5.3.6. In the first sensitivity analysis, the 'no change responses' were removed from the dataset. Subsequently, the influence of the price level of the charges was studied for the reduced dataset. Only the influence of price level (and not of for example mean annual toll costs or overall costs) was studied because price level directly relates to the composition of the price measure and may therefore be particularly interesting to policy-makers. Additionally, it was too time-consuming to include all the price configurations in the sensitivity analysis. As a consequence, the sensitivity analyses were only carried out for measures 1 (fixed kilometre charge), 2B (the car weight dependent charge) and 3 (the time-dependent kilometre charge) in which price levels vary systematically. In contrast no price level differentiation occurs for measure 2A.

A possible problem that occurs when leaving out the zero value responses is that the size of the dataset is reduced (i.e. due to the large number of no change responses), which sometimes may mean that the results are affected by the sample size. For this reason another sensitivity analysis was conducted as well. On the basis of the total sample (including the zero values) Tobit and Poisson regression models were estimated with price level (and revenue use) as independent explanatory factors. As described in chapter 3 (section 3.5.4), Tobit regression is a suitable regression technique when the dependent variable is measured on an interval or ratio

99 See, for example, the influence of the price level of a time-differentiated kilometre charge (i.e. price measure 3) on trip change behaviour.

scale and the variable is censored. Tobit analysis can be carried out for the absolute as well as the relative shape of the dependent variable. As a sort of extra analysis we used Poisson regression. Poisson regression can be used to estimate models for count data (see chapter 3, section 3.5.5). The absolute trip change can be seen as a count-value: respondents choose how many of the current trips by car they want to adjust. This implies that the Poisson regression can only be used for the 'absolute trip change' variable.

It must be emphasized here that the initial aim was to use rather well-known and easy techniques (i.e. t-tests and ANOVA analyses) for the analysis reported in this chapter. The main reason for this was that the short-term trip effects for households do not directly belong to the core of this thesis, which, as described in chapter 1, focuses primarily on the effects of pricing policies from a (transport) geographical point of view. However, the initial results forced us to use some more specific techniques in a sensitivity analysis. If from the outset we had given a higher priority to analysing the influence of price levels on people's travel behaviour, analytical techniques such as Tobit regression would probably have been used for all analyses.

The descriptions presented above mainly refer to household questionnaire 2. But data of another dataset, namely household questionnaire 3, is also used in the analysis in this chapter. Questionnaire 3, focused on the shopping motive. Each respondent was presented with one type of price measure (e.g. a kilometre or cordon charge) and one price level (high or low charge). The revenue use was not varied (see Table 5.2). Because total annual toll trip costs were not shown to respondents within questionnaire 3, only the influence of the price level was tested (see section 5.3.4), for each motive (daily or non-daily shopping) and price measure separately. Sensitivity analyses were not conducted for questionnaire 3, because of the relatively small size of the sample.

5.3.2 - Commute trips

5.3.2.1 - Changes in commuting trips per price measure: a descriptive analysis

The intended changes of respondents in their commuting trip behaviour due to different pricing measures are presented in Table 5.3. The price measures are indexed in the columns, while the changes in behaviour are presented in the rows. Table 5.3 shows that, on average, over all four measures, 16.4 percent of the respondents chose to adapt their behaviour. The time-dependent measures (2a and 3) show relatively higher adaptation percentages than the other two measures (1 and 2B). Furthermore, on average 0.5 percent of the respondents want to make more trips due to the pricing measures. It can also be observed that the percentage of the total commuting trips to be adjusted is lower than the percentage of respondents who want to change their behaviour. Again, the highest adaptations are found for the two time-dependent charges (measure 2A and 3).

The trips to be changed were distributed over different alternatives. With regard to the flat kilometre charge, respondents most often chose the alternatives slow traffic and public transport: on average they want to divert 32 percent of the current car commuting trips they intend to adjust to the slow traffic mode and also about 32 percent to public transport. Carpooling is regarded as a third interesting option. The time-differentiated charges 2A and 3 (i.e. higher charge in peak period) show another picture. 'Travel at other times' is regarded by far as the most interesting option (51 and 48 percent respectively). Public transport comes in second place. Slow traffic is

Table 5.3: changes in the current commuting trip pattern by car due to different pricing measures

Price measure	1 Flat km charge	2A Km charge + bottleneck toll	2B Car weight km charge	3 Time differentiated km charge
Total number of commute trips (4 weeks)	6800	3188*	3612	6800
People who want to change trips	11.3 % (45)	19.7 % (37)	9.0 % (19)	25.6 % (102)
Trips adjusted	5.9 % (400)	11.2 % (358)	4.0 % (145)	14.8 % (1004)
Of which:				
Public transport	31.8 % (127)	22.3 % (80)	13.8 % (20)	17.6 % (177)
Slow traffic	32.2 % (129)	8.9 % (32)	26.2 % (38)	12.7 % (128)
Other motorized (own)	9.5 % (38)	2.5 % (9)	38.6 % (56)	8.9 % (89)
Carpool	19.5 % (78)	10.6 % (38)	12.4 % (18)	4.5 % (45)
Travel other times	x	51.1 % (183)	x	47.7 % (479)
Work at home	6.5 % (26)	4.2 % (15)	6.9 % (10)	8.0 % (80)
Not making trip	0.5 % (2)	0.3 % (1)	2.1 % (3)	0.6 % (6)

* Because either measure 2A or 2B was presented to the respondents, only the sum of the total trips for 2A and 2B (i.e. 3188 and 3612) is the same as the total number of trips for the other two measures (i.e. 6800).

Table 5.4: mean absolute change in current car trips per price measure (one-way Anova)

Commute	Distribution			P (Post Hoc test Bonferroni*)			
Price measure	Mean	Std. dev.	N	Measure 1	Measure 2A	Measure 2B	Measure 3
1	1.0050	3.4793	398	-	0.116	1.000	0.000
2a	1.9043	4.6551	188	0.116	-	0.032	0.645
2b	0.6905	2.7572	210	1.000	0.032	-	0.000
3	2.5226	5.4853	398	0.000	0.645	0.000	-

F = 11.883, p = 0.000

* Post hoc tests can determine which means differ. The Bonferroni (post hoc) test is a commonly used multiple comparison test. It is based on Student's t-statistic and adjusts the observed significance level for the fact that multiple comparisons are made. The Bonferroni test is powerful for a small number of pairs such as in the situation here (SPSS, 2006). For other post hoc multiple comparison tests see SPSS (2006).

seen as a less feasible option compared to the flat kilometre charge. With respect to the measure differentiated towards car weight (i.e. 2B), respondents regard other motorized modes, such as motorcycles or mopeds, as most interesting, followed by slow traffic. Public transport is somewhat less popular but comes in third place.

Thus, respondents seem to regard 'travelling at other times' as a good alternative in the case of a time-dependent charge. As far as the price measures are concerned, which are not differentiated on the basis of time, public transport and slow modes are interesting alternatives. The options working at home (on average around 6 percent) and not making the trip at all (approximately 1 percent) are the least attractive.

5.3.2.2 – Influence of the price measure on car trip change: a statistical analysis

Table 5.3 showed that people's intention to modify their travel behaviour was relatively higher for time-differentiated charges (i.e. measures 2A and 3). A one-way Anova analysis was carried out to determine whether there are significant (95 percent level) differences in the reported intended changes for commuting between the measures. The results for the absolute change in car trips are presented in Table 5.4, and the results indicate that the time-differentiated kilometre charge (measure 3) leads to a significantly higher absolute (car) trip change compared to the flat kilometre charge (measure 1) and the kilometre charge differentiated with respect to car weight (measure 2B). Moreover, measure 2B on average leads to a significantly lower trip change than a flat kilometre charge with an additional time-differentiated peak charge (measure 2A). Differences between measures 1 and 2A and between 3 and 2A were not found to be significant. Results observed in the case of using the relative number of car trips changed as dependent variable pinpoint in the same direction. The only important change being that the difference between the flat kilometre charge with an additional time-differentiated peak charge (measure 2A) and the kilometre charge differentiated with respect to car weight (measure 2B) becomes more significant (i.e. p = 0.022).

5.3.2.3 - Influence of the price level and revenue use on car trip change: a statistical analysis

For each price measure additional analyses were carried out to gain insight into the influence of the price/charge and the effect of the type of revenue use on trip change. The results are separately discussed for each price measure.

Price measure 1: flat kilometre charge

As shown in Table 5.1, the flat kilometre charge (measure 1) consists of three price levels (3, 6 and 12 eurocent/km) and two types of revenue use (abolition or reduction of fixed car taxes and lowering income taxes). With respect to the price level, a significantly (p = 0.028) higher relative commuting trip change was found for the highest price level of 12 eurocent/km compared to the lowest level of 3 cent/km. The highest price level also leads to a higher relative trip change in relation to the level 6 cent/km. However, this latter result is only significant with a reliability of 90 percent (p = 0.055). If the absolute number of car trips changed is used as the dependent variable, the difference between the lowest and highest charge level is not significant. In addition to the price level itself, the questionnaire automatically computed and showed the personal annual toll costs to each respondent (i.e. the number of annual kilometres driven multiplied with the price level). The mean and median values were computed on the basis of all these annual individual costs. Subsequently, trip change differences between respondents, who were expected to have to pay less or more than the average or median value, were analyzed by means of a T-test. Although respondents who were expected to pay more reported slightly higher average trip change rates, these results were not found to be significant with a reliability of 95 percent (either for absolute or relative trip changes).

Table 5.5: mean absolute and relative change in current car trips per type of revenue use (T-test)

Price measure 1 commute	**Absolute trip change**			**Relative trip change**		
	Mean	**Std. Dev.**	**N**	**Mean**	**Std. dev.**	**N**
Abolishment existing car taxes	0.33	1.607	200	0.0275	0.13205	200
Lowering income taxes	1.69	4.565	198	0.0990	0.25471	198
	Difference	t	p (2-tailed)	Difference	t	p (2-tailed)
T-test	-1.37	-3.976	0.000	-0.0715	-3.510	0.001

The influence of revenue use on the absolute and relative number of trips changed was tested as well. Table 5.5 shows the results. The left part represents the results for the average absolute trip change; the right part shows the relative trip change. In both cases (absolute and relative change), respondents who were presented with the revenue use 'reducing income taxes' indicated a significant (99 percent level) higher trip change intention compared to the revenue use 'abolition (or reduction)[100] of existing fixed car taxes'. Two possible reasons can be given for this outcome, one related to the revenue use itself and one methodological reason. The revenue use 'abolition of existing car taxation' is related more to the transport system than a general lowering of income taxes. This may result in a higher perceived benefit in the former case and in the end to a lower trip change. Furthermore, for the revenue use 'abolition of existing car taxation', explicit cost benefits were presented to respondents; this was not done for the 'reduction of income taxes'. The effect of this additional information may be that respondents are able to imagine the (size of the) benefits more clearly in practice, and as a consequence they indicate a lower trip change intention in the case of the 'abolition of existing car taxation'.

Because benefits due to the revenue use 'abolition existing car taxes' were described to the respondent in greater detail compared to the general 'lowering of income taxes', additionally separate analyses were carried out on one sub-sample that only contained respondents who were presented with the first and, one sample with people who were presented with the second type of revenue use (see figure 5.1). Within the sub-samples the influence of price levels and annual toll costs were tested. Moreover, the influence of whether respondents in total would gain or loose due to the kilometre charge could be tested for the sub-sample 'abolishment of existing car taxes' too (see section 5.3.1).

With respect to the dataset that only contained the revenue use 'abolition of existing car taxes', we found that an increase in annual car cost (annual kilometre charge – reduction in fixed car taxes) leads to a significant ($p = 0.028$) higher reduction in absolute current car trips compared to an overall decrease in annual cost. However, the mean value of car trip change is still slightly positive for the situation in which total costs decrease (i.e. mean value = 0.07 car trips changed on a four week basis). When using the relative car trip change as the dependent variable, an increase of car costs also seems to lead to a higher (relative) car trip change, although this result is only significant with a reliability of 90 percent ($p = 0.053$). Furthermore, the mean and median values for the annual toll costs were computed. People who were presented a higher toll cost than the median value reported a relatively higher trip change intention both in an absolute ($p = 0.016$) and in a relative sense ($p = 0.024$). For the mean value, slightly higher p-values were found: absolute car trip change ($p = 0.048$), relative car trip change ($p = 0.052$). Finally, as is the case with the total dataset, the difference between the highest and lowest price level is significant when using 'the relative car trip change' as the dependent variable.

If we only include respondents who were presented with a 'reduction of income taxes', no significant results appear. Neither the annual charge (mean and median value) nor the price level

100 This is dependent on the price level (see Table 5.1). For high price levels, we assumed existing car taxes would be abolished. For lower price levels, car taxes are only reduced, in such a way that the price measure on average does not increase the governments' traffic-related revenues compared to the current situation with fixed car taxes.

(3, 6, 12 euro cent/km) leads to significant differences in the (absolute and relative) number of car trips changed.

Price measure 2: kilometre charge + bottleneck toll or a car weight dependent kilometre charge
As shown in Table 5.1, price measure 2 consists of two alternatives. Measure 2A is a flat kilometre charge plus a time-dependent peak charge at congested bottlenecks. Measure 2B is a kilometre charge differentiated according to three weight classes of the car: the higher the weight, the higher the charge. Both measures were presented as being budget neutral to the government. The revenue use was formulated as a reduction or abolition of fixed car taxes.

Separate analyses with respect to the price level were conducted for both price measures (see figure 5.1). The influence of three (cost) dummies was tested for both measures: (i) increase/decrease in total costs (i.e. annual charge – revenue gains), (ii) higher/lower than the mean value of annual toll costs, (iii) higher/lower than median value of annual toll costs. Focusing on the flat kilometre charge plus a time-dependent peak charge at congested bottlenecks (measure 2A), the first finding is that an increase in total costs (for respondents) leads to a relatively higher (absolute) number of car trips changed compared to a decrease in cost ($p = 0.018$). When using the relative trip change as dependent variable, results are not significant ($p = 0.112$). By contrast, using the mean or median value of annual toll costs leads to significant results for both the absolute as well as the relative change in car trips. Results for the mean value are shown in Table 5.6: respondents that were presented with a higher annual charge than the mean value indicated a significantly higher (reliability of 99 percent) car trip change intention.

For the kilometre charge differentiated according to car weight (measure 2B) no significant influence of toll costs on car trip change was found. Neither price level differences nor the dummies with regard to people being above or beneath the mean or median toll costs or having to pay more or less as a result of the charge (and revenue use) led to significant differences in the car trip change.

Price measure 3: time-differentiated kilometre charge
With regard to the time-differentiated kilometre charge (price measure 3) the same procedure was followed as for the flat kilometre charge (price measure 1). First, the influence of the price level itself and the effect of paying more or less than the annual (mean and median) toll costs was tested on the basis of the total sample. Secondly, the influence of the type of revenue use (lowering income taxes versus lowering fixed car taxes) was studied. In addition, the influence of

Table 5.6: mean absolute and relative change in current car trips for measure 2A (T-test)

Price measure 2a commute	Absolute trip change			Relative trip change		
	Mean	Std. dev.	N	Mean	Std. dev.	N
Km charge/yr						
< mean 790 euro/yr	0.8431	2.92932	98	0.0629	0.20156	102
>= mean 790 euro/yr	3.1628	5.87689	102	0.1749	0.32055	86
	Difference	t	p (2-tailed)	Difference	t	p (2-tailed)
T-test	-2.3197	-3.329	0.001	-0.1120	-2.806	0.006

toll costs was analyzed separately for sub-samples containing only one type of revenue use (see figure 5.1).

Looking at the total dataset, neither price level nor the (mean or median) annual toll cost variations led to significant differences in car trip change. Furthermore, no significant influence of the type of revenue was shown. For the sub-samples only one significant price effect was observed. An increase in the overall annual car costs on the basis of the peak charge (i.e. annual costs for driving only in the peak period – lowering fixed car taxes) results in a higher car trip change intention ($p = 0.016$). When the off-peak or the mean charge (mean between peak and off-peak) are used instead of the peak charge, the significance is reduced (respectively $p = 0.086$ and $p = 0.054$). These results may indicate that with respect to commuting, respondents evaluate their personal consequences on the basis of the highest charge level, possibly because they expect they will be driving to work especially during these 'expensive' periods.

5.3.3 - Social (visit) trips

5.3.3.1 - Changes in the social (visiting) trips per price measure: a descriptive analysis
The changes respondents intend to make in their current social (visiting) trips by car due to different pricing measures are described in Table 5.7. Around a quarter of the respondents indicated they would change their behaviour due to the flat and time-differentiated kilometre charges (measures 1 and 3). The percentages found for measures 2A and 2B are slightly lower (respectively 19 and 17 percent). With respect to the percentage of intended changes the same picture emerges: the flat kilometre charge (measure 1) and the time-differentiated kilometre charge (measure 3) result in the highest adaptation in social car trips; the change due to the flat kilometre charge plus time-differentiated toll at bottlenecks (measure 2A) is slightly higher than it is for measure 2B (a kilometre charge differentiated according to the weight of the car).

Comparing the percentages of adjusted trips for the categories commuting (see Table 5.3) and social trips (Table 5.7), there is a striking difference. The percentage of social trips respondents intend to adjust due to the flat kilometre charge or weight differentiated charge (measure 1 and 2B) is higher compared to commuting. For the flat kilometre charge there is an increase from 5.9 percent for commuting to 14.2 percent for social (visiting); for the car weight dependent charge (measure 2B) the percentage increases from 4.0 to 8.4 percent. In contrast, for the time-differentiated measures, 2A and 3, the adjustment percentage is (slightly) lower for social purposes compared to commuting. A possible explanation for these differences may be found in the essence of trips made for commuting and social purposes. Generally speaking people are more constrained when it comes to commuting. People may not have a real alternative to going by car (e.g. long distance, no public transport connection, etc.) if a charge is introduced which is not differentiated in time[101]. Because they have no choice but to commute, respondents more often take the possibly higher costs for granted. This can explain the lower percentage of change in commuting trips for the flat kilometre and car weight dependent measures (1 and 2B). When it comes to social trips, on the other hand, people have a greater degree of latitude and these kinds

101 Departure time alteration is a change that is made more easily than (the) other changes, which often involve a change of mode of transportation or not driving at all.

Table 5.7: changes in the current social (visiting) trip pattern by car due to different pricing measures

Price measure	1 Flat km charge	2A Km charge + bottleneck toll	2B Car weight km charge	3 Time differentiated km charge
Total number of social trips (4 weeks)	3620	1824	1796	3620
People who want to change trips	26.4 % (119)	19.4 % (45)	16.5 % (36)	25.3 % (114)
Trips adjusted	14.2 % (513)	9.1 % (166)	8.4 % (150)	14.6 % (529)
Of which:				
Public transport	17.7 % (91)	16.9 % (28)	14.0 % (21)	13.6 % (72)
Slow traffic	44.6 % (229)	29.5 % (49)	46.7 % (70)	28.0 % (148)
Other motorized	9.0 % (46)	1.2 % (2)	8.7 % (13)	1.7 % (9)
Carpool	x	x	x	x
Travel other times	x	42.2 % (70)	x	47.8 % (253)
Work at home	x	x	x	x
Not making trip	28.7 % (147)	10.2 % (17)	30.7 % (46)	8.9 % (47)

of trips are often made outside the peak hours or in weekends anyway. Therefore, the option 'departure time change' in the case of a time-differentiated charge may be less interesting.

Focusing more specifically on the alternatives that are chosen for car trips, some clear differences occur between those measures, which are and are not differentiated in time. With respect to the flat kilometre charge (measure 1) and the kilometre charge differentiated according to car weight (measure 2B), slow traffic is seen as the most interesting option. Approximately 45 percent of the car trips that were selected for adaptation were assigned to slow traffic (i.e. bike, walking). This also indicates that destinations for social trips are often close to residential areas. Furthermore, the option 'not making the trip' is also chosen regularly in the case of the flat kilometre charge (measure 1) as well as for the 'car weight charge' (measure 2B). This seems to indicate that respondents want to make more efficient (or less) social trips. Public transport only comes on a third place with percentages roughly twice as small as 'not making the trip'.

For the time-differentiated measures (2A and 3), we find that the option 'travelling at other times' is chosen most often (approximately 42 percent for measure 2A and 48 percent for measure 3)[102], followed by slow traffic. In contrast to measures that are not time-differentiated, the public transport option on average seems to be preferred to not making the trip at all. Looking more closely at Table 5.7, it is rather striking that the percentage of current car trips that is to be diverted to public transport is rather stable over the measures. Compared to the measures that are not time-differentiated, the category 'travel at other times' gets its high share especially at the expense of options 'slow traffic' and 'not making the trip', and not from public transport. Thus, there seems to be a sort of fixed core of people who regard public transport as an interesting alternative. Finally, focusing again on Table 5.7, the option 'other owned motorized transport (e.g. mopeds, motor cycles)' is the least favourite option for all measures.

102 Thus, although time differentiation may be less interesting for reducing costs with respect to social (visiting) trips, possibly leading to a relatively lower overall adjustment percentage compared to commuting time, time change seems to be an interesting alternative for respondents who did choose to adjust their social trips.

5.3.3.2 – Influence of the price measure on car trip change: a statistical analysis
Two one-way Anova analyses were carried out to test the significance of the differences between the four price measures. One analysis was carried out for the absolute number of trips changed, while the other analysis used the relative trip change as a dependent variable. Using the relative trip change as the dependent variable, the only significant difference (99 percent) occurs between the time-differentiated kilometre charge (price measure 3) and the car weight dependent kilometre charge (measure 2B). The time-differentiated kilometre charge (measure 3) leads to a significantly higher relative trip change than the kilometre charge differentiated with respect to car weight (measure 2B). Furthermore, the difference between measure 1 and measure 2B is only significant with a reliability of 90 percent. Other differences are not significant by far. The same goes for all differences when using the absolute number of trips changed as the dependent variable.

5.3.3.3 – Influence of the price level and revenue use on car trip change: a statistical analysis
As for commuting, separate analyses for each price measure were conducted to obtain insight into the influence of the price level, the total annual (toll) costs and the type of revenue use on people's willingness to change their travel behaviour (see figure 5.1). In the following subsections, the results for the individual price measures are described.

Price measure 1: flat kilometre charge
To test the influence of the height of the charge and the type of revenue use, three datasets are used (see also section 5.3.1). First, the influence of price and the type of revenue is tested for the total sample. Subsequently, the effect of price on trip change is evaluated for two sub-samples. One sub-sample only contains the revenue use 'lowering fixed taxes'. The other sample includes 'lowering income taxes'. This procedure is chosen because the benefits of 'lowering fixed car taxes' are expressed in costs, which is not the case for 'lowering income taxes'. This means that the influence of total car costs (costs – benefits) on trip change behaviour can also be tested for the former sample.

Table 5.8 shows the influence of the price level (total sample) on the share of current car trips that are adjusted for the social (visiting) motive. The highest price level leads to a significant higher trip change ($p = 0.033$). Differences in trip change between other price levels are not significant. The same picture was also found for absolute car trip change: there is only a significant difference between the highest and lowest charge ($p = 0.040$).

In addition to the influence of price level, we looked at the effect of total annual charging costs (on the basis of annual kilometres driven). The results indicate that respondents who have to pay more than the mean or median annual toll costs change a greater number of trips than respondents who are below the average or median. This significant result (95 percent level) is found for the absolute and relative trip change variable. Furthermore, the effect of the type of revenue use was also tested. Although respondents are less willing to change their behaviour when they are confronted with the revenue use 'reduction of fixed car taxes' (compared to 'reduction of income taxes'), this result is only significant with a reliability of 90 percent.

For the sub-sample that only contains the revenue use 'lowering fixed car taxes', the influence of a total increase or decrease of car costs can be computed (toll costs – reduction in fixed car taxes).

Table 5.8: mean relative change in current social car trips per price level for measure 1 (one-way Anova)

Social (relative)	**Distribution**			**P (Post Hoc test Bonferroni)**		
Price level measure 1	**Mean**	**Std. dev.**	**N**	**3 cent**	**6 cent**	**12 cent**
3	0.0945	0.22600	160	-	1.000	0.033
6	0.1172	0.21019	145	1.000	-	0.286
12 cent	0.1635	0.26860	145	0.033	0.286	-

F = 3.345, p = 0.036

Table 5.9: mean absolute and relative change in current social car trips due to change in total car costs (T-test); sub-sample with revenue use 'lowering of fixed car taxes' only.

Price measure 1 social	**Absolute trip change**			**Relative trip change**		
	Mean	**Std. dev.**	**N**	**Mean**	**Std. dev.**	**N**
Abolishment existing taxes	0.6190	1.63719	105	0.0724	0.17916	124
Lowering income taxes	1.0968	2.56118	124	0.1317	0.24259	105
	Difference	t	p (2-tailed)	Difference	t	p (2-tailed)
T-test	-0.4777	-1.706	0.089	-0.0593	-2.123	0.035

The results are shown in Table 5.9. An increase in the total costs leads to a significantly higher relative car trip change. Using the absolute change as the dependent variable leads to a difference that is only significant at the 90 percent level.

On the basis of the same subset the influence of price level was also found to be significant; as for the total dataset, a higher relative trip change is found for the highest (12 eurocent/km) compared to the lowest charge level (3 eurocent/km). Additionally, the difference between the highest and medium price (6 eurocent/km) is significant as well. Significant differences were, however, not found on the basis of the 'absolute' trip changes. Furthermore, the difference in behaviour between respondents that have to either pay more or less than the mean or median annual toll costs (without the inclusion of benefits) is not significant at the 95 percent level.

Finally, the influence of toll costs was tested for the subset that only contains respondents who were presented with the revenue use 'lowering income taxes'. Analyses indicate that as for the total sample, respondents with a annual toll cost above the mean or median value have a significantly higher absolute trip change intention (95 percent). The relative differences are only significant at the 90 percent level.

Price measure 2: kilometre charge + bottleneck toll or a car weight dependent kilometre charge
As described before and as was shown in Table 5.1, price measure 2 is divided into two alternatives: measure 2A is a flat kilometre charge plus a time-differentiated toll charge. Measure 2B is a kilometre charge differentiated according to vehicle weight. For both measures we looked at the influence of charge costs and total car costs (charge costs – benefits due to lowering fixed car taxes). Additionally, the influence of charge level (i.e. three levels dependent on car weight) was also tested for measure 2B.

For the flat kilometre charge plus the time-differentiated toll (measure 2A), we examined the influence of a decrease or increase of total car costs on trip change. The differences in (absolute or relative) trip change for an increase or decrease of costs were not found to be significant. In the same line the absolute trip change comparing respondents who pay more or less than the mean or median value of the annual (personal) charge costs proved not to be significantly different. The only significant difference is observed for the mean value of charging costs in the case of using 'relative' trip change as the dependent variable: respondents who pay more than the mean annual toll costs have a significant higher relative trip change intention ($p = 0.045$).

Moreover, the influence of different toll cost variables was tested for measure 2B. However, no significant differences in trip change (both absolute as well as relative changes) due to price were found.

Price measure 3: time-differentiated kilometre charge
The same procedure as for the flat kilometre charge (measure 1) was followed to test the influence of toll costs and the type of revenue use on car trip change intentions. No significant effect of price (and revenue use) on social trip changes was found, which either holds for the total or for the sub-samples constructed on the basis of the type of revenue use.

5.3.4 - Other trips

5.3.4.1 - Changes in the other trips per price measure: a descriptive analysis
Table 5.10 provides an overview of the results for the category 'other trips'. The results are similar to those observed for social trips (see Table 5.7), although for the latter purpose (i.e. social) the trip change percentages are slightly higher. For the flat kilometre charge (price measure 1) and the kilometre charge differentiated to car weight (2B), which are both not differentiated in time, slow traffic is the alternative that is chosen most often (approximately 65 percent for measure 1 and 67 percent for measure 2B). The second and third most frequently selected alternatives are 'not making the trip' and 'public transport'. This same could be seen in the case of social trips (see

Table 5.10: changes in the current 'other' trip pattern by car due to different pricing measures

Price measure	**1**	**2A**	**2B**	**3**
	Flat km charge	**Km charge + bottleneck toll**	**Car weight km charge**	**Time differentiated km charge**
Total number of other trips (4 weeks)	7780	3892	3888	7780
People who want to change trips (%)	23.9 % (125)	20.3 % (54)	16.8 % (43)	22.2 % (116)
Trips adjusted	10.9 % (846)	9.2 % (359)	7.9 % (308)	13.2 % (1028)
Of which:				
Public transport	13.4 % (113)	13.1 % (47)	9.7 % (30)	14.1 % (145)
Slow traffic	64.9 % (549)	38.7 % (139)	66.6 % (205)	28.9 % (297)
Other motorized	1.8 % (15)	1.7 % (6)	1.0 % (3)	1.5 % (15)
Carpool	x	x	x	x
Travel other times	x	38.2 % (137)	x	47.3 % (486)
Work at home	x	x	x	x
Not making trip	20.0 % (169)	8.4 % (30)	22.7 % (70)	8.3 % (85)

5.3.3.1). With respect to the time-differentiated measures 2A and 3, the option 'travelling at other times' was selected most often (respectively around 38 and 47 percent), followed by slow traffic and public transport. This is again in line with results for the social purpose.

There are also small differences in results between the trip purposes 'other trips' and 'social trips'. Slow traffic is chosen more often as an alternative for car trips with the purpose 'other'. This is especially the case for measures that are not time-differentiated (measures 1 and 2B). An explanation for the fact that slow traffic becomes a more interesting option (compared to the social motive) may be that trips that fall into the category 'other', such as shopping, going to sports etc., often involve small distances, in which case people may prefer slower mode options.

5.3.4.2 – Influence of the price measure on car trip change: a statistical analysis
To test the significance of the difference in car trips adjusted between the different price measures, two one-way Anova analyses were carried out: one with the absolute change and the other with the relative car trip change as the dependent variable. The results are quite in line with the results observed for the social (visiting) purpose (see also section 5.3.3.2): the only significant (95 and even 99 percent level) difference in trip change occurs between the time-differentiated kilometre charge (measure 3) and the car weight dependent charge (2B). This result is based on using the relative trip change as the dependent variable. When we used the absolute trip change as the dependent variable, no significant differences between the four price measures were found.

5.3.4.3 – Influence of the price level and revenue use on car trip change: a statistical analysis
Like we did with commuting and social trips, we looked at the influence of toll price and revenue use on trip change with other purposes for each of the price measures separately. Again, a distinction is drawn between carrying out analyses on the total dataset and on subsets (i.e. subsets that contain a specific type of revenue use).

Price measure 1: flat kilometre charge
On the basis of the total dataset the influence of price level (i.e. 3, 6 and 12 eurocent/km) and of having to pay more or less than the mean (or median) annual kilometre charge costs has been tested. No significant differences in trip change intentions were found between the separate price level classes. Furthermore, having to pay more or less than the mean annual charging costs (price level * number of annual kilometres) does not lead to a significant (95 percent level)[103] difference in car trip change. For the median value a significant result is found in the relative car trip change (p= 0.031); the difference in the case of focusing on the absolute trip change is only significant at a 90 percent level. In addition to the charge, the effect of the type of revenue use was tested; trip change differences due to revenue use were not found to be significant.

Additionally, analyses were carried out on two sub-samples, which were based on the type of revenue use. No significant differences in trip change due to toll costs were found for the subset that only contained the revenue use 'lowering income taxes'. On the other hand, focusing on the sample with the revenue use 'lowering fixed car taxes', a significant difference in car trip change

103 However, there seems to be a trend that respondents who have to pay toll costs that are higher than the mean value indicated a relatively higher trip change intention (p = 0.072 for absolute number of trips changed and p = 0.099 for the relative car trip change).

Table 5.11: mean absolute and relative change in current car trips for change in total car costs (T-test); sub-sample with revenue use 'lowering of fixed car taxes' only.

Price measure 1 other	Absolute trip change			Relative trip change		
	Mean	Std. dev.	N	Mean	Std. dev.	N
Decrease cost	0.8099	2.46074	121	0.0611	0.16614	121
Increase cost	1.7956	3.85040	137	0.1196	0.22333	137
	Difference	t	p (2-tailed)	Difference	t	p (2-tailed)
T-test	-0.9857	-2.478	0.014	-0.0585	-2.404	0.017

occurred between those whose total car costs (toll costs – revenue benefits) increase or decrease (see Table 5.11): higher costs lead to a higher trip change (absolute and relative).

Moreover, the influence of annual toll costs (price level * kilometres driven) was analyzed (i.e. for the sub-sample 'lowering/abolishing fixed car taxes'). No statistical significant results were derived. However, respondents who have to pay more than the mean or median toll costs tend to indicate a greater willingness to change their behaviour. These results are significant at the 90 percent level for the absolute as well as the relative trip change, and are in line with the outcomes derived on the basis of the total sample.

Price measure 2: kilometre charge + bottleneck toll or a car weight dependent kilometre charge
Price measure 2 is divided into two alternatives: measure 2A and 2B (see Table 5.1). The question of whether people are better or worse off due to the charge (expressed in costs) has a significant effect on absolute car trip change due to measure 2A (i.e. fixed kilometre charge plus a time-differentiated toll on bottlenecks). This can also be seen in Table 5.12. When using the relative number of trip changes, on the other hand, the difference is only significant at a 90 percent level. Subsequently, the influence of the total annual toll costs (price level * kilometres driven) was tested. These results are not significant.

The variable increase or decrease of total costs (annual toll costs – revenue benefits) has a significant influence on the number of car trip changes in the case of the car weight dependent charge (measure 2B). Respondents for whom the total costs would increase (on the basis of their personal driving pattern) indicated a significantly higher relative trip change ($p = 0.018$). The differences in the number trip changes due to price height are not significant.

Table 5.12: mean absolute and relative change in current car trips for change in total car costs (T-test)

Price measure 2A other	Absolute trip change			Relative trip change		
	Mean	Std. dev.	N	Mean	Std. dev.	N
Decrease cost	0.7863	2.55405	131	0.0711	0.19794	131
Increase cost	1.8963	4.38837	135	0.1211	0.25375	135
	Difference	t	p (2-tailed)	Difference	t	p (2-tailed)
T-test	-1.1100	-2.530	0.012	-0.0501	-1.797	0.074

*Table 5.13: mean absolute and relative change in current car trips for change in total car costs (T-test); the independent variable is based on the peak charge (peak charge * kilometres – revenue benefits); sub-sample with revenue use 'lowering of fixed car taxes' only.*

Price measure 3 other	**Mean**	**Std. dev.**	**N**	**Mean**	**Std. dev.**	**N**
Decrease cost	0.2683	0.92262	41	0.0346	0.11633	41
Increase cost	2.0524	5.89505	229	0.1199	0.25792	229
	Difference	t	p (2-tailed)	Difference	t	p (2-tailed)
T-test	-1.7841	-4.295	0.000	-0.0854	-3.427	0.001

Price measure 3: time-differentiated kilometre charge

With regard to the time-differentiated kilometre charge the influence of the height of the charge was tested for the total sample and for two sub-samples created on the basis of the type of revenue use. Beginning with the total sample, only the median annual toll level dummy resulted in a significant difference in relative trip change; respondents who have to spend more than the median value on annual toll costs reported a significantly higher relative trip change (p = 0.012). The mean value is only significant at the 90 percent level. In addition to that, no significant results were found when using the absolute number of car trips changed as the dependent variable, nor were there indications that the price level has any significant influence on relative or absolute trip change. Finally, the type of revenue use does not lead to significant differences in trip change.

For the sub-sample based on 'reducing fixed car taxes', price level differences (i.e. price/km) or the annual toll cost (mean and median value) do not cause any significant differences in trip change behaviour. The only significant differences are caused by the variable 'increase or decrease in annual car cost'. Dummies for increase/decrease of annual costs were constructed on the basis of the peak charge[104], the off-peak charge[105], and the mean charge[106]. The highest levels of significance are found for the peak charge (see Table 5.13: p = 0.000 for absolute and p = 0.001 for relative trip change). The off-peak charge leads to the lowest significance (p = 0.783 for absolute and p = 0.036 for relative trip change). The values for the mean charge are somewhere in between (both at least significant at the 90 percent level). The results seem to indicate that respondents focus particularly on the highest presented price level.

Finally, the influence of price level and annual toll costs was analyzed for the sub-sample containing the revenue use 'lowering income taxes'. These analyses did not produce any significant results.

104 Annual kilometres * the peak charge. This assumes that people drive all their annual kilometres in the peak period (high charge).

105 Annual kilometres * the peak charge. This assumes that people drive all their annual kilometres in the off-peak period (low charge).

106 Annual kilometres * average charge. The average charge is the mean of the peak and off-peak charge.

5.3.5 - Shopping trips (daily and non-daily)

5.3.5.1 - Changes in the shopping trips per price measure: a descriptive analysis

As far as the analysis of changes in car trips for daily and non-daily shopping was concerned, a different dataset was used (see section 5.2), which makes it harder to compare the results to the results outlined above. Because the trip motive 'other trips' (see section 5.3.4) implicitly contains shopping trips, the obvious thing to do is to confront the results on the basis of this trip motive. Moreover, a similarity between the datasets is that trip change behaviour due to a time-differentiated kilometre charge occurs in both data files. A quick comparison of the percentage of trips adjusted for the trip motive 'other trips' (Table 5.10: differentiated kilometre charge 3) and daily shopping (Table 5.14 differentiated kilometre charge), learns that the relative trip changes are quite in line (approximately 13 percent). However, for non-daily shopping a higher percentage of intended change emerges (around 19 percent). This higher percentage might be explained by non-daily shopping trips being less constrained and therefore easier to change compared to daily grocery trips.

The trip adjustment percentages due to the cordon charge are higher than for the kilometre charge. Especially the difference for daily shopping is quite large. This difference might be partly caused by the configuration of the questionnaire. In the cordon charge related questionnaire(s), respondents were asked questions regarding daily shopping by car in one of the four largest cities in The Netherlands[107]. Around these four cities a 'city inward' cordon charge was assumed (see Table 5.2). For the kilometre charge on the other hand, all daily shopping trips by car were included, no matter what shopping destination. Therefore, daily shopping locations within the kilometre charge questionnaires may be located closer to the respondents' residential location. When a cordon charge is implemented, respondents may try to change these (less efficient) trips, which makes the higher level of adjustments due to the cordon charge understandable. Indeed, this effect can be observed in Table 5.14. The most frequently chosen alternative for current daily

Table 5.14: changes in the (non) daily shopping trip pattern by car due to different pricing measures

Trip purpose	**Daily shopping/week**		**Non-daily shopping/year**	
Price measure	**Time-dependent km charge**	**Cordon charge**	**Time-dependent km charge**	**Cordon charge**
Total number of trips	244.2	156.7	1803	1174
People who want to change trips (%)	16.5 % (20)	32.9 % (25)	33.8 % (47)	47.6 % (59)
Trips adjusted	12.7 % (31)	19.0 % (29.7)	19.1 % (344)	24.3 % (285)
Of which:				
Public transport	3.2 % (1)	20.2 % (6)	32.7 % (112.5)	32.2 % (92)
Other transport	58.1 % (18)	13.5 % (4)	x	x
Travel other times	6.5 % (2)	6.7 % (2)	15.0 % (51.5)	3.9 % (11)
Combining trips	9.7 % (3)	13.5 % (4)	x	x
Change location	0.0 % (0)	24.2 % (7.2)	20.3 % (70)	24.2 % (69)
Not making trip	22.6 % (7)	21.9 % (6.5)	32.0 % (110)	39.6 % (113)
N	121	76	139	124

107 Where (in most cases) they did not live.

shopping trips (by car) is 'changing the location of daily shopping' (24 percent). In the kilometre charge questionnaires no one chose this option.

Focusing on other alternatives for daily shopping by car, Table 5.14 shows that for the time-differentiated kilometre charge the option 'other transport' (e.g. slow modes, motorbikes, mopeds) is selected most often (58 percent). In second place comes 'not making the trip'. For the cordon charge the category 'other transport' comes only in fourth place when we look at the choice frequency. Public transport is often chosen in the case of the cordon charge, whereas public transport appears to be less attractive when a kilometre charge is introduced. Finally, in line with the results for the kilometre charge, the option not making the trip also offers an important alternative in the case of a cordon charge.

The specific difference in questionnaire configuration in the case of daily shopping does not exist for non-daily recreational shopping. In both situations (i.e. in the cordon and kilometre charge questionnaire) recreational shopping was (i.e. in the cordon and kilometre charge questionnaire) defined as non-daily shopping by car in another city. Inspection of the distance to the most frequently visited 'shopping' city revealed that there are no significant differences with regard to the mean distance (both 28 kilometres) between the two sub-samples. The only difference is that the cordon charge measure focused on non-daily shopping to (one of) the four largest cities, while the choice of destination was not restricted in the kilometre charge. The difference in terms of the intended changes may be explained by the general characteristics of cordon charges. A cordon charge is more spatially differentiated than a kilometre charge that applies on all roads. This spatial differentiation may give people a higher motivation and opportunity to change their (travel) behaviour in order to divert charging costs. Moreover, a kilometre charge is a less instantaneous and more gradual measure than a cordon charge: in the case of the cordon measure the driver has to pay a relatively high fee at one instant. This high price might lead to a substantial boundary to pass the cordon and overall result in a larger change in trip behaviour. However, in addition to general characteristics of the measures, the chosen price levels may also help explain differences in trip change. On the basis of the average distance to the city where the respondents go most often to do their recreational shopping (28 kilometres), the kilometre charge leads to a lower overall trip-based charge compared to the cordon measure. A higher price may result in a higher trip change intention.

With regard to non-daily shopping, the preferred alternatives for car trips are quite similar for both price measures. On average 'Not making the trip' is chosen most often (approximately 35 percent), followed closely by public transport. 'Change location' comes in third place. The options 'other transport' and 'combining trips' could not be selected as options for current car trips, because they were thought to be non-realistic in advance (see section 5.2).

Finally, the preferred options for the social, 'other' and shopping categories seem to be similar with respect to the alternatives 'slow traffic' and 'not making the trip'. These options are regularly chosen in all three cases. There is a striking difference, however, with respect to the alternative 'travel at other times'. This option was often chosen for the social and 'other' categories, but less frequently in relation to shopping. This is hard to explain and may have to do with the fact that different data sets are used. For the shopping-related questionnaire (i.e. household questionnaire 3, see section 5.2), some additional questions were asked regarding the period of the day or week during which most of the shopping trips are made. More than 80 percent of the daily shopping trips are already made in off-peak hours or weekends. For non-daily shopping this percentage amounts to around 90 percent. This means that people already tend to do their shopping in 'cheap' periods, which makes changing the time of the trips a less fruitful option in the case of time-differentiated pricing measures[108].

5.3.5.2 – Influence of the price measure on car trip change: a statistical analysis

Again, the influence of the type of price measure on trip change was tested. However, in this situation there were only two measures available: the time-differentiated kilometre and cordon charge. No significant difference in trip change between the two measures was observed. For daily shopping, there seems to be a trend that the cordon charge leads to a higher relative and absolute trip change. This difference is only significant with a reliability of 85 percent. As far as non-daily shopping was concerned no clear difference was observed.

5.3.5.3 – Influence of the price level and revenue use on car trip change: a statistical analysis

Both the kilometre charge and the cordon charge consisted of two price level variants (see Table 5.2). In contrast to household questionnaire 2, the total annual costs on the basis of the annual number of kilometres driven by car were not presented to the respondents in the shopping questionnaire[109]. Furthermore, the type of revenue use[110] was kept constant. Thus, only the influence of the price level itself was tested.

No significant differences in car trip change were found between measures. The results are even counterintuitive, with a higher charge leading to a lower trip change. The unexpected results may be due to the fact that each respondent evaluated only one price level (i.e. only inter-personal price effects could be assessed). Another reason may be the sample size. Differentiating the sample into four subsets (to account for the four questionnaire versions) results in samples containing only 40 to 70 respondents, which may influence the results.

5.3.6 - The influence of the price level more closely examined: a sensitivity analysis

As described in section 5.3.1, some sensitivity analyses were carried out to gain more insight into the influence of the price level of the charge on the (relative and absolute) intended trip changes. This was done because higher pricing charges quite often did not lead to significantly higher car trip change intentions and because there was some doubt that this partly have been caused by taking zero values (i.e. 'no trip change' responses) into account in the dependent variable. These 'zero' trip changes decrease the average trip change frequency of all respondents. This in turn may mitigate possible significant price level effects for people who do decide to change their behaviour. Therefore, section 5.3.6.1 reports on the results of the sensitivity analysis in which the influence of the price level was studied on the basis of a dataset from which the

108 Whether or not respondents in the other household questionnaire (i.e. household questionnaire 2) currently use their car often for social and other motives outside the peak periods could not be tested, because these questions were not asked.

109 Total annual costs could not be computed because it was a paper questionnaire survey that was carried out in one questionnaire round.

110 Revenues go to the government and are used for all kinds of things such as education, health care, financing of deficits, etc.

‘no change’ responses were removed. The analytical techniques are the same as the ones we used before. Subsequently, 5.3.6.2 uses estimation techniques that are more suitable with respect to the composition of the dependent variable. These techniques are Tobit and Poisson regression. The possible advantage of the method to be used in section 5.3.6.2 above the procedure applied in section 5.3.6.1 is that no ‘precious’ data is left out.

5.3.6.1 – Influence of the price level in a reduced dataset: Anova analyses

In this sensitivity analysis, no significant differences in car trip change intentions due to price level were found, either for the flat kilometre charge measure (price measure 1) or for the measure with price levels differentiated according to car weight (measure 2B), or for the time-differentiated kilometre charge (measure 3). Moreover, no significant effects were found for any of the trip motives (commuting, visit, other purposes). There is no clear explanation for the insignificant results. It may be partly due to smaller sample sizes, which may cause differences to be insignificant.

A striking trend, although not a significant one, is that the lowest price level often leads to a higher intended mean car trip change than the ‘medium’ price level. This trend occurs in the case of a flat kilometre charge (measure 1) or a time-dependent kilometre charge (measure 3). In some cases the intended trip change is even higher for the low price level than it is for the highest price level. This result is counterintuitive. A possible explanation is that when only the ‘do want to change trips’ responses are taken into account, the relative influence of price in the case of a low charge is overestimated: the mitigating effect on trip change results of respondents who only want to change car trips at higher levels is left out. The group of respondents who intend to change behaviour at a lower price level may, therefore, be more cost sensitive, possibly leading to higher mean trip changes. However, this reasoning is fairly speculative and has not been verified. Overall, it can be concluded that no clear influence of the height of the price level on car trip change intention was found. In conclusion, this first sensitivity analysis in no way proved that the level of the price has a bigger influence on trip change intention when ‘no change’ responses are left out. In fact, the results suggest an even lower influence of price level.

5.3.6.2 – Influence of the price level on the basis of Tobit and Poisson regression

Tobit and Poisson regression analyses were carried out in line with what was announced in section 5.3.1: Tobit regressions were applied for absolute and relative trip change formulations of the dependent variable; Poisson regression was used only for the absolute trip change variable.

The most striking outcome of the analyses is that differences in the mean car trip change due to the price level are often significant when using Poisson regressions, whereas hardly any significant price level effects are retrieved from the Tobit analyses. Therefore, primarily results from the Poisson regression analyses are presented here (without ignoring Tobit results in the conclusions of this section). Table 5.15 shows the influence of the price level of three different kilometre charges on the absolute number of changes in commuting trips. Results were obtained via Poisson regressions. As was to be expected, a higher charge level in the case of a flat kilometre charge (measure 1) leads to a significantly higher mean trip change: the negative signs for ‘price level low’ and ‘price level medium’ indicate a lower average trip change than observed for the highest charge level. Additionally, the average intended trip change is significantly lower for the lowest compared to the medium price level. These results are only partly in agreement with the

Table 5.15: influence price level and revenue use on commute car trip change for different price measures

Commute: absolute car trip change (Poisson regression)	M1: Flat km charge (measure 1)		M2: Car weight km charge (measure 2B)		M3: Time-differentiated km charge (measure 3)	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
constant	-0.7176	0.0000	-0.1032	0.4840	0.9949	0.0000
dummy price level low	-0.7388	0.0000	-	-	-0.1786	0.0163
dummy price level medium	-0.6879	0.0000	-	-	-0.3898	0.0000
dummy RU lowering income tax	1.6632	0.0000	-	-	0.2186	0.0006
dummy car medium weight	-	-	-0.3958	0.0801	-	-
dummy car heavy weight	-	-	-0.3572	0.0638	-	-
N (number of respondents)	398		210		398	
Log likelihood	-1050.8		-420.1		-1820.5	
Log likelihood (convergence)	-924.6		-418.0		-1803.1	
X^2	252.3		4.1		34.7	

results obtained in section 5.3.2.3. There, a higher intended trip change was observed for higher price levels only when the relative (and not the absolute) trip change was regarded. Within the same model in Table 5.15 the influence of the type of revenues use was tested. When revenues are used to reduce income tax the mean trip change is higher compared to when they are used to reduce or abolish fixed car taxes. This result was also found in section 5.3.2.3.

For the car weight related kilometre charge (measure 2B), the results are found to be significant with a reliability of 90 percent. Respondents with lighter cars on average adjust more car trips than respondents who have heavier cars. On first sight this seems strange given the fact that heavier cars are tolled higher in this price measure alternative. A possible explanation is that respondents with lighter car are more cost-sensitive or willing to change their behaviour. They may, for example, not be able to buy or maintain a heavier car or choose a lighter car for environmental reasons (i.e. lower fuel consumption). In addition, respondents with lighter cars may be less fond of driving a car: smaller cars are only used for practical purposes. Especially with regard to commuting, which generally spoken involves longer trips that are made more frequently than other kinds of trips, higher changes for more cost-sensitive persons may occur. Another possible explanation is that lighter cars may sometimes be used as a 'second' car in households. Trips changes may occur especially for these cars because they are more of a luxury than the first car. For comparison no significant effects of the car weight on trip change was observed in section 5.3.2.3. Finally, Table 5.15 shows that the results for the time-differentiated charge (measure 3) are quite comparable to the results for the flat kilometre charge. The only difference is that the medium charge level leads to a lower intended mean car trip change than the lowest price level. In contrast, no significant influences of price level differences or revenue use on car trip change were found in section 5.3.2.3.

Table 5.16 shows the Poisson regression results for the trip purpose social visits. The results for the flat and time-differentiated kilometre charges (i.e. measure 1 and 3) are comparable to the results for commuting reported in Table 5.15. The only difference is that the influence of the type of revenue use is not significant for the time-differentiated kilometre charge in the case of the trip purpose social visit. For measure 2B, no significant differences in the mean intended car trip

Table 5.16: influence price level and revenue use on (social) car trip change for different price measures

Social: absolute car trip change (Poisson regression)	M1: Flat km charge (measure 1)		M2: Car weight km charge (measure 2B)		M3: Time-differentiated km charge (measure 3)	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
constant	0.2134	0.0122	-0.1566	0.2291	0.3938	0.0000
dummy price level low	-0.7317	0.0000	-	-	-0.3152	0.0018
dummy price level medium	-0.4215	0.0001	-	-	-0.5596	0.0000
dummy RU lowering income tax	0.4881	0.0000	-	-	0.0696	0.4240
dummy car medium weight	-	-	-0.0601	0.7411	-	-
dummy car heavy weight	-	-	-0.2389	0.1448	-	-
N (number of respondents)	450		296		450	
Log likelihood	-1040.0		-528.3		-1075.1	
Log likelihood (convergence)	-1002.2		-527.0		-1061.3	
X^2	75.6		2.5		27.6	

Table 5.17: influence price level and revenue use on (social) car trip change: Poisson and Tobit regression

Social: flat kilometre charge (price measure 1)	M1: absolute change (Poisson regression)		M2: absolute change (Tobit regression)		M3: relative change (Tobit regression)	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
constant	0.2134	0.0122	-4.1223	0.0000	-0.3297	0.0002
dummy price level low	-0.7317	0.0000	-3.5649	0.0017	-0.2980	0.0029
dummy price level medium	-0.4215	0.0001	-1.5455	0.1549	-0.1285	0.1812
dummy RU lowering income tax	0.4881	0.0000	1.8670	0.0408	0.1480	0.0659
sigma	-		7.4579	0.0000	0.6645	0.0000
N (number of respondents)	450		450		450	
Log likelihood	-1040.0		-		-	
Log likelihood (convergence)	-1002.2		-549.5		-268.8	
X^2	75.6		-		-	

change due to car weight are found. Comparing the results in Table 5.16 with the Anova and t-test results in section 5.3.3.3 shows us that the results for the flat kilometre charge (measure 1) are quite in line. The only difference is that in section 5.3.3.3 no significant difference between the medium price level and the other price levels was found. The results of the weight-differentiated kilometre charge in section 5.3.3.3 also appeared to be insignificant. For the time-differentiated kilometre charge (measure 3) no significant influence of price level changes was found, whereas there appears to be a price level effect when Poisson regression is used.

As indicated at the beginning of this section, hardly any significant price level effects are retrieved when using Tobit regression. The best Tobit regression results with respect to statistical significance are obtained for price measure 1 and the trip purpose social visiting. Table 5.17 shows these results on the basis of both the Tobit and the Poisson regression. Results for all three models in Table 5.17 are comparable. As for the Poisson regression (model M1), the Tobit regressions also indicate a lower mean intended car trip change when the price level is lower. The influence of the medium price level is, however, not significant. Moreover, Tobit regression results estimated for the absolute form of the dependent variable (model M2) are in accordance with relative change results (model M3).

Poisson regression results for the rest category 'other trips' are presented in Table 5.18. For the time-differentiated kilometre charge (measure 3) results are similar to those found for the commuting and social (visiting) trip purposes. Again, the highest price level leads to the highest car trip change, although the medium charge level leads to a smaller decrease compared to the low charge. For the flat kilometre charge the same trend is maintained: the highest charge leads to the highest adaptation and the car trip change for the lowest charge level is higher than for the medium charge. This latter result contrasts with the results for commute and social visit purposes where the lowest charge yielded the lowest level of trip change. There is no clear explanation for this difference. For the weight differentiated kilometre charge, finally, the results contradict the commuting results. Respondents with heavier cars indicated they would change more trips with regard to the rest category 'other trip purposes', whereas commuting trips showed the opposite results. The higher level of trip changes for heavier cars may be due to the nature and characteristics of trips in the category 'other' purposes. 'Other' trips may in general be shorter and less obligatory and constrained than, for example, commuting and visit trips. This may provide respondents with heavier cars a greater incentive change their behaviour compared to other respondents. When the price effect for the trip purpose 'other trips' are compared to the Anova results in section 5.3.4.3, the differences are considerable. In section 5.3.4.3, no significant differences in car trip change due to the height of the price level were found, whereas the Poisson results in Table 5.18 point at significant price influences.

In conclusion, the Poisson regression analyses indicated some significant price level effects. In general, the influence of price level and revenue use changes seem to be as expected: higher mean car trip changes are found for higher price levels and respondents who were presented with the revenue use of 'lowering income taxes' were observed to adapt more current car trips than when 'lowering of fixed car taxes' was used. These results are still quite in line with the results from Anova analyses en t-tests presented in the previous sections. The major difference is that results in general are more significant when Poisson regression analyses are used. A striking

Table 5.18: influence price level and revenue use on changes in 'other' car trips for different price measures

Other: absolute car trip change (Poisson regression)	**M1: Flat km charge (measure 1)**		**M2: Car weight km charge (measure 2B)**		**M3: Time-differentiated km charge (measure 3)**	
	Coefficient	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**
constant	0.4888	0.0000	-0.1335	0.2413	0.6869	0.0000
dummy price level low	-0.2165	0.0069	-	-	-0.0934	0.2031
dummy price level medium	-0.4106	0.0000	-	-	-0.2657	0.0007
dummy RU lowering income tax	0.3464	0.0000	-	-	0.2043	0.0011
dummy car medium weight	-	-	0.4052	0.0021	-	-
dummy car heavy weight	-	-	0.2978	0.0500	-	-
N (number of respondents)	522		345		522	
Log likelihood	-1734.7		-986.8		-2192.6	
Log likelihood (convergence)	-1710.1		-981.8		-2181.7	
X^2	49.1		10.1		21.7	

effect is that for the time-differentiated measures a significantly higher trip change is found for the medium price level compared to the lowest price level. Although this applies to all three categories, it is hard to explain. Price level or revenue use effects usually appear to be insignificant when Tobit regressions are used. These insignificant results are retrieved both when the absolute and the relative form of the dependent variable is used. However, in most cases the signs of the coefficients and their relative strength correspond to the results from the Poisson regression.

The price level effects observed in this section are largely in line with the results reported by Ubbels (2006), who analyzed with Tobit regression techniques among other things the influence of the price level on the relative trip change intention on the basis of the same data set used in this chapter. Ubbels estimated separate models per price measure, using a data file in which trip change intentions for all trip purposes were combined[III]. In line with our results, Ubbels (2006) reported that price level differences have a more significant influence on trip change intention in the case of the flat kilometre charge (measure 1) compared to the time-differentiated kilometre charge (measure 3). As was reported here (see Table 5.15 and 5.16), Ubbels also found the 'strange' outcome for the time-differentiated kilometre charge that the medium price level leads to a lower trip change intention compared to the lowest price level. Furthermore, although the direction of price level effects for the flat kilometre charge (measure 1) we observed in our Tobit regression analyses (i.e. higher trip change intentions for higher price levels) correspond to the results presented by Ubbels (2006), his results in contrast were significant (99 percent level). This may have been caused by his larger sample in which trip change intentions for all trip motives were combined. Ubbels also tested the influence of the type of revenues use on trip change intention. These results correspond to the results presented in this chapter.

In the sensitivity analyses presented in this section we did not find evidence for the proposition made earlier that the occasionally unclear influence of the price height on trip change (observed in the previous sections) may have been caused by the large number of 'no change' (i.e. zero value) responses in the dependent variable. Although Poisson regressions pointed to a stronger relationship between price level and trip change, this was not confirmed by the Tobit analyses. The question is what technique is the most suitable here. Because Tobit regressions are designed in particular to be used in the case of censored datasets, this may make them more suitable, given the fact that the dependent variable is censored at zero. On the other hand, respondents only could decide to change a rounded number of car trips for each time period (i.e. integer values). The dependent variable thus has the 'form' of count data. Poisson regressions are suitable if the dependent variable is a count-variable, while Tobit analyses assume that the dependent variable is measured on an interval or ratio scale. From this point of view Poisson regression analysis may be the more eligible technique. However, the large number of zero values (representing no car trip change) may also have had a negative impact on Poisson regression results. Excess zeros may lead to an effect called 'overdispersion' (for an explanation, see e.g. Cameron and Trivedi, 1990; Zorn, 1996; Greene, 2002). In situations with possible overdispersion other generalized linear models, such as the negative binomial model, may function better. A sensitivity analysis (not reported in this thesis) into price level effects was also conducted using a negative binomial model. This analysis showed that price level effects are clearly less significant compared to using the Poisson regression, although they are in general more significant than Tobit regression results. Anyway,

III Dummy variables for trip purpose were included in the estimation procedure.

leaving the question of the most appropriate technique in the middle it can at least be concluded that although higher price levels in general seem to result in higher trip changes, the data used did not reveal a (strong) relation between price level (price per kilometre) and trip change.

The existence of 'weak' price height effects does not necessarily mean that people are insensitive to price. It may also have something to do with the way people make choices. Kahneman (2003) states: "The central characteristic of people is not that they reason poorly but that they often act intuitively. And the behaviour of these agents is not guided by what they are able to compute, but what they happen to see at a given moment." In the case of the 'pricing of goods', for example, scope neglect and violation of monotonicity can occur (see Kahneman, 2003). An example of scope neglect given by Kahneman is that of survey respondents in Toronto who were willing to pay almost as much to clean up the lakes in a small region of Ontario as they were to clean up all the lakes in that province. However, violation of monotonicity may be more relevant as an alternative explanation for the rather weak influence of price level differences. Kahneman (2003; p 1465) gives an example indicating that there is an important difference between the price people will pay for a good when they only see one of the products (separate evaluation), and when they see both products at the same time. In the questionnaire we used in this chapter to analyze price effects, respondents were shown only one price level. According to Kahneman, intuition seems to dominate people's responses in such separate evaluations. This may have (some) effect on the price level influences, which in the study reported in this chapter were examined at an inter-personal level.

5.4 - Influencing factors for car trip change due to pricing

Section 5.3 focused on descriptive analyses of trip change behaviour and on the influence of price measure characteristics. In the current section we go one step further and provide insight into influencing (especially socio-economic, demographic and trip related) factors with regard to car trip change due to pricing measures. Section 5.4.1 describes the methodology that was applied. The results are presented in section 5.4.2.

5.4.1 - Applied methodology

A study into influencing factors was carried out, as it can give valuable information regarding what type of respondents are more or less willing to change their behaviour as a result of various pricing measures. Such information may also be important for decision-makers, for example in tailoring pricing measures or in deciding how revenue rebates can best be reinvested in society. The analyses of the explanatory factors were carried out on the basis of household questionnaire 2. Household questionnaire 3 was not used because of its relatively low sample size and the limited number of possible explanatory factors available in the dataset. Analyses were carried out for each trip purpose separately: commuting, social and other trips. This made it possible to study differences in (type and strength of) explanatory factors for different trip purposes. Instead of estimating models with explanatory factors for each trip purpose separately, we could also have decided to estimate 'explanatory' models for each type of pricing measure independently as was done by Ubbels as indicated in the previous section (see for results Ubbels, 2006). We decided against doing that because we expected that there are more major differences in (socio-economic and demographic) influencing factors between models that are estimated for different

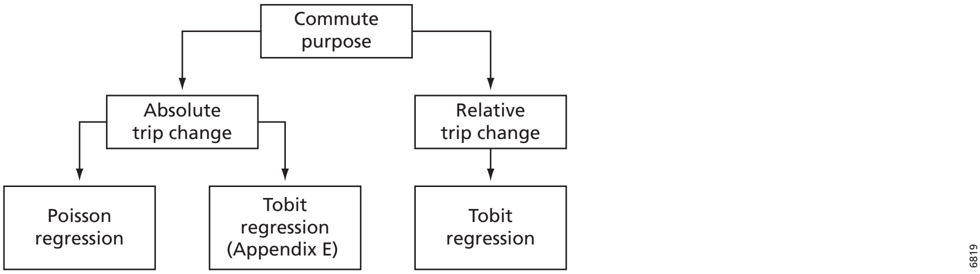


Figure 5.2: schematic overview of the analysis into explanatory factors (commute trips)

trip purposes than between models that are estimated for different price measures only. However, whether this actually is true has not been verified by ourselves. At least the choice to estimate models for each trip purpose separately is in accordance with the structure of section 5.3, where the results were examined for each of the trip purposes separately. Moreover, the influence of different price measure features (e.g. price height, revenue use) on trip change behaviour has already been statistically examined in this chapter. This makes it less necessary also to estimate models for separate price measures in this section. However, the influence of the type of price measure on trip change was still included in the estimations by incorporating dummy variables for the different price measures.

Figure 5.2 provides an overview of the analyses that were carried out for commuting trips. Separate models were estimated using either the absolute or the relative trip change as the dependent variable. This distinction is made because, as we described in section 5.3.1, it may be interesting from a methodological point of view to study differences in results between both types of dependent variables. To gain insight into influencing factors, Poisson and Tobit regression analyses were carried out. Poisson regression is a suitable statistical technique for analyzing count data (e.g. trip change = 0, 1, 2..., n), with the dependent variable being positive ($y \geq 0$) (see also section 3.5.4). In the case of the relative trip change, Poisson regression cannot be used, because the dependent variable does not contain count data when relating the absolute trip change to the current number of car trips made for a certain purpose. To gain insight into influencing factors for the relative trip change, Tobit regression estimations were carried out. Tobit analyses are useful when the data are censored. In this specific case, the data are censored at 0 ($y \geq 0$) (see also section 3.5.4); zero means that the respondents do not intend to change their behaviour. To compare outcomes for both statistical methods, Tobit regressions were also estimated on the basis of the absolute trip change dependent variable. Anticipating on the results that are presented in the next section, more significant explanatory effects were observed when we used Poisson regressions than when we used Tobit regressions, which is why we decided to present (only) the results of Poisson regressions in cases where the *absolute trip change* is used as the dependent variable. Some sensitivity analysis results are provided in Appendix E, where commuting-related results are presented of Poisson and Tobit regression models estimated using the same set of independent explanatory variables. Because, as indicated above, Poisson regression cannot be used to estimate models on the basis of the 'relative' trip change, Tobit regression results estimated on the basis of the *relative trip change* variable are presented in the next section as well.

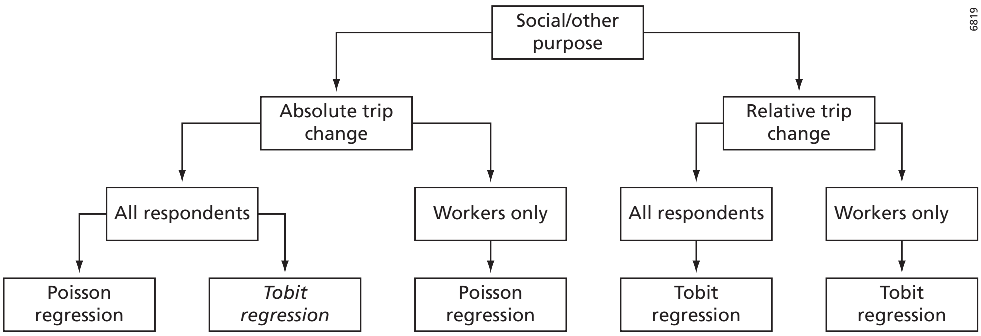


Figure 5.3: schematic overview of the analysis into explanatory factors (social and other purpose trips). The analysis in italic (Tobit regression for absolute trip change) was carried out but results are not explicitly reported in this thesis (see also Appendix E).

In the same way, figure 5.3 gives an overview of the analyses that were carried out for social and 'other' trip purposes. In principle the same approach was used as for commuting trips, with only one difference. For both trip purposes, models were estimated on two different sample sizes: a sample containing all respondents and a sample in which only respondents with (paid) work were included. This distinction is made because the expectation is that when not only people having work are included, work related factors such as travel cost compensations may become less influential.

The models presented in this section were derived by following a certain estimation procedure. First, the explanatory power of the individual independent variables was tested. Then, significant individual factors were combined into a single model. Insignificant factors (e.g. due to correlation effects) were then removed until a model remained with explanatory variables that are significant with a reliability of at least 90 percent. No strong correlation effects were found in the remaining models. There are two exceptions with respect to the procedure of removing statistically insignificant factors: neither income nor price measure dummies were deleted, even when the dummy effects were not significant. This was done because of the 'principal' importance of both types of variables in (road) pricing studies.

5.4.2 - Estimation results

The results are described in two subsections. Section 5.4.2.1 focuses on explanatory factors that appear to have a significant explanatory power in general (i.e. in most models). Section 5.4.2.2 presents the most striking estimation-related (methodological) differences between the models.

5.4.2.1 – General explanatory variables

Detailed estimation results for commuting, social and other trips are provided in Tables 5.20 to 5.22 respectively. For the reader's convenience, however, the main results are summarized and simplified in Table 5.19. Income is an important explanatory factor in all models. As expected, a higher income appears to lead to a significant lower trip change intention (absolute as well as relative) for all trip motives (see also Ubbels, 2006). This is not always the case for consecutive classes: sometimes a higher trip change is found for a lower than for the next higher income interval.

Table 5.19: sign of significant explanatory variables with respect to car trip change for three trip motives (ns = not significant)

Sign explanatory factors in relation to car trip change	Commute	Visit	Other
Income	-	-	-
Age	-	-	ns
Gender	-	-	+
Education	+	-	+
Annual km driven	+	+	+
Commute distance	+	ns	ns
Travel cost compensation	-	-	-
Possibility to work at home	+	ns	+
Child(ren)	ns	-	-
Single	ns	ns	-
Weight car	+/-	-	-
Number of cars in household	ns	+	ns
Frequency in congestion	ns	+	+
Living in a 'congested' region	+	-	+/-

The influence of demographic variables such as age, gender and education was tested as well. Respondents with an age above the mean value of the sample (39 years) reported a significant lower intention to make changes in their commuting and social (visiting) car trips. People of middle and higher ages may have optimized their activity pattern due to years of experience/ behaviour. This may have resulted in a stronger habitual behaviour compared to younger people, making it less likely that they change their existing behaviour. For the purpose 'other trips', age was not found to be significant. Subsequently, women indicated a significant lower intention to change commute and social car trips than men. Possibly working women are more time-constrained than men since they often combine work with caring tasks. Current trip patterns may already be specifically tailored to be able to carry on tight schedules. This might well mean that women have a lower incentive to change current social and commuting car trips. For other trips, however, the opposite seems to be true: women are more willing than men to change 'other' trips made by car.

In addition to that, education is significant for all trip motives. For commuting and other trips a positive sign can be observed, indicating that respondents with a higher education level (college or university) are more inclined to change their behaviour with respect to commuting and other trips. By contrast, more highly educated respondents intend to adjust their social (visiting) trips by car to a lower extent than people who are less highly educated. This may be caused by an effect that cannot be tested on the basis of the data. Highly educated people in general have more specialized jobs that are not available everywhere. Therefore, people may have to follow jobs, thereby increasing the distance to their close relatives. Additionally, more highly educated respondents may have friends (for example from their study period) that live further away. Because this involves crossing larger distances, alternative modes of transportation are often available to a lesser extent or are less attractive, possibly leading to a relatively lower change in current social related car trips for higher educated people.

Several trip and work-related characteristics are explanatory as well. As expected, respondents driving more kilometres (in one car) on an annual basis than the mean value of the sample (i.e. 15,000 kilometre) indicated a relatively higher change in current car trips for all three categories (commuting, social and other). Ubbels (2006) in contrast finds, although not statistically significant, that respondents driving more kilometres per year have a lower trip change intention. Related to the commuting trip is the commute distance (one-way). Working respondents with a commuting trip length of more than the median value (25 kilometres) chose to change more current commuting trips by car than those with a lower trip length. For the other two trip motives, this variable was not found to be significant. In addition to the commuting or total number of kilometres, the variables 'travel cost compensation' and the 'possibility to work at home' are explanatory. Respondents receiving a total compensation of their travel (commuting) costs indicated a significant lower intention to change car trips made for all trip motives. A logical explanation for this is that respondents that receive a travel cost compensation experience

Table 5.20: explanatory variables for changing commuting car trips due to pricing (absolute and relative change)

Change current car trips for commute due to pricing (absolute and relative change)	**M1: absolute change (Poisson regression)**		**M2: relative change (Tobit regression)**	
	Coefficient	**P-value**	**Coefficient**	**P-value**
Constant	-0.7175	0.0000	-1.4409	0.0000
dummy annual gross household income (<28.500 euro=1)	-0.4746	0.0000	-	-
dummy annual gross household income (28.500-45.000 euro=1)	-0.2507	0.0000	-	-
dummy annual gross household income (45.000-68.000 euro=1)	-	-	-	-
dummy annual gross household income (>68.000 euro=1)	-0.6022	0.0000	-0.3384	0.0046
dummy age respondent (≥ median value of 39 years =1)	-0.2473	0.0000	-	-
dummy gender (female=1)	-0.3107	0.0000	-	-
dummy education (college, university=1)	0.3522	0.0000	0.2327	0.0070
dummy annual km in car (> median value of 15.000 km =1)	0.4203	0.0000	-	-
dummy commute dist. car one-way (> median value of 25 km =1)	0.1508	0.0079	-	-
dummy travel cost compensation employer (completely compens.=1)	-0.7348	0.0000	-0.2152	0.0195
dummy possibility to work at home (always or sometimes =1)	0.2402	0.0000	0.3075	0.0007
dummy car low weight (yes=1)	0.6348	0.0000	0.2447	0.0070
dummy heavy car (yes=1)	0.3958	0.0000	-	-
dummy living in a region with congestion problems (yes=1)	0.1028	0.0459	-	-
dummy price measure 1	0.3668	0.0003	0.1452	0.2883
dummy price measure 2A	1.0941	0.0000	0.5305	0.0004
dummy price measure 3	1.3661	0.0000	0.6867	0.0000
sigma	-		0.9079	0.0000
N (number of choices)	1137		1137	
N (number of respondents)	379		379	
Log likelihood	-4068.2		-	
Log likelihood (convergence)	-3518.4		-543.4	
X^2	1099.5		-	

Table 5.21: explanatory variables for changes in the social category due to pricing (absolute and relative change); analyzed for all respondents and for working people only

Change current car trips for social (visiting) due to pricing measures 1, 2, 3 (absolute and relative change)	**M1: absolute change (Poisson regression)**		**M2: absolute change (Poisson regression)**		**M3: relative change (Tobit regression)**		**M4: relative change (Tobit regression)**	
	all respondents		**only respondents having a paid job**		**all respondents**		**only respondents having a paid job**	
	Coefficient	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**
Constant	0.7035	0.0000	-0.7180	0.0000	-0.6538	0.0000	-0.9673	0.0000
dummy annual gross household income (<28,500 euro=1)	-	-	-	-	-	-	-	-
dummy annual gross household income (28,500-45,000 euro=1)	-0.3383	0.0000	-0.1487	0.0918	-	-	-	-
dummy annual gross household income (45,000-68,000 euro=1)	-0.3272	0.0000	-0.7259	0.0000	-	-	-	-
dummy annual gross household income (>68,000 euro=1)	-0.5648	0.0000	-0.5386	0.0000	-0.3370	0.0001	-0.2853	0.0044
dummy age respondent (≥ median value of 39 years =1)	-0.2630	0.0000	-0.2274	0.0016	-	-	-	-
dummy education (college, university=1)	-0.3004	0.0000	-	-	-	-	-	-
dummy gender (female = 1)	-0.3165	0.0000	-	-	-	-	-	-
dummy child (yes=1)	-0.3107	0.0000	-0.3729	0.0000	-	-	-	-
dummy paid job (yes=1)	-1.1642	0.0000	-	-	-0.3381	0.0001	-	-
dummy living in a region with congestion problems (yes=1)	-0.3751	0.0000	-0.1698	0.0177	-0.0981	0.0889	-	-
dummy days per week congestion delay (≥3 times=1)	0.3089	0.0000	0.2658	0.0003	0.1609	0.0134	0.1647	0.0206
dummy annual km in car (> median value of 15,000 km =1)	0.5672	0.0000	0.5603	0.0000	0.2001	0.0026	0.1631	0.0455
dummy travel cost compensation employer (completely compens.=1)	-	-	-0.7193	0.0000	-	-	-0.1595	0.0366
dummy car low weight (yes=1)	0.5060	0.0000	0.1903	0.0158	0.1799	0.0040	0.2055	0.0090
dummy number of cars in household (more than one=1)	0.4169	0.0000	0.7326	0.0000	0.1877	0.0018	0.1590	0.0245
dummy price measure 1	0.4930	0.0000	0.7380	0.0000	0.2606	0.0035	0.2628	0.0155
dummy price measure 2A	0.0062	0.9956	0.0998	0.5022	0.0959	0.3536	0.0827	0.5090

Change current car trips for social (visiting) due to pricing measures 1, 2, 3 (absolute and relative change)	M1: absolute change (Poisson regression) all respondents		M2: absolute change (Poisson regression) only respondents having a paid job		M3: relative change (Tobit regression) all respondents		M4: relative change (Tobit regression) only respondents having a paid job	
	Coefficient	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**
dummy price measure 3	0.5220	0.0000	0.6378	0.0000	0.2828	0.0015	0.2681	0.0100
sigma	-		-		0.7590	0.0000	0.7594	0.0000
N (number of choices)	1305		903		1305		903	
N (number of respondents)	435		301		435		301	
Log likelihood	-2839.3		-1691.3		-		-	
Log likelihood (convergence)	-2589.8		-1878.3		-759.4		-521.8	
X^2	499.0		374.0		-		-	

Table 5.22: explanatory variables for changing 'other' car trips due to pricing (absolute and relative change); analyzed for all respondents and for workers only

Change current car trips for purpose 'other' due to pricing measures 1, 2, 3 (absolute and relative change)	**M1: absolute change (Poisson regression)**		**M2: absolute change (Poisson regression)**		**M3: relative change (Tobit regression)**		**M4: relative change (Tobit regression)**	
	all respondents		**only respondents having a paid job**		**all respondents**		**only respondents having a paid job**	
	Coefficient	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**
Constant	0.6033	0.0000	-0.7492	0.0000	-1.0466	0.0000	-1.0464	0.0000
dummy annual gross household income (<28,500 euro=1)	-	-	-	-	0.1785	0.0391	0.1490	0.1504
dummy annual gross household income (28,500-45,000 euro=1)	-0.5327	0.0000	-0.0567	0.4047	0.0981	0.2226	0.1001	0.2844
dummy annual gross household income (45,000-68,000 euro=1)	-0.3470	0.0000	-0.2329	0.0010	0.1821	0.0233	0.1759	0.0520
dummy annual gross household income (>68,000 euro=1)	-0.3378	0.0000	0.0372	0.6617	-	-	-	-
dummy education (college, university=1)	0.1326	0.0049	0.2667	0.0000	-	-	-	-
dummy gender (female = 1)	0.1841	0.0000	0.3197	0.0000	-	-	-	-
dummy child (yes=1)	-0.7511	0.0000	-0.4442	0.0000	-	-	-	-
dummy single household (yes =1)	-0.9118	0.0000	-0.7596	0.0000	-	-	-	-
dummy paid job (yes=1)	-0.8369	0.0000	-	-	-	-	-	-
dummy living in a region with congestion problems (yes=1)	-0.1279	0.0022	0.0890	0.0892	-	-	-	-
dummy days per week congestion delay (≥3 times=1)	0.2450	0.0000	0.1332	0.0097	-	-	-	-
dummy annual km in car (> median value of 15,000 km =1)	0.5501	0.0000	0.9104	0.0000	0.1746	0.0007	0.1604	0.0183
dummy travel cost compensation employer (completely compens.=1)	-	-	-0.5299	0.0000	-	-	-0.1814	0.0073
dummy possibility to work at home (always or sometimes =1)	-	-	-	-	-	-	0.1183	0.0655
dummy car low weight (yes=1)	0.8506	0.0000	0.7522	0.0000	0.2303	0.0016	0.2819	0.0016

Change current car trips for purpose 'other' due to pricing measures 1, 2, 3 (absolute and relative change)	**M1: absolute change (Poisson regression)**		**M2: absolute change (Poisson regression)**		**M3: relative change (Tobit regression)**		**M4: relative change (Tobit regression)**	
	all respondents		**only respondents having a paid job**		**all respondents**		**only respondents having a paid job**	
	Coefficient	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**
dummy medium weight (yes=1)	0.6059	0.0000	0.3470	0.0000	0.1613	0.0121	0.1889	0.0142
dummy price measure 1	0.2782	0.0000	0.4555	0.0000	0.1786	0.0196	0.2046	0.0191
dummy price measure 2A	0.0857	0.2713	0.3775	0.0001	0.1263	0.1512	0.1704	0.0978
dummy price measure 3	0.4778	0.0000	0.5618	0.0000	0.1943	0.0111	0.1941	0.0266
sigma	-		-		0.7102	0.0000	0.6994	0.0000
N (number of choices)	1518		1068		1518		1068	
N (number of respondents)	506		356		506		356	
Log likelihood	-5426.2		-3593.8		-		-	
Log likelihood (convergence)	-5016.7		-3291.0		-833.2		-595.2	
X^2	819.0		605.6		-		-	

a lower incentive to change something: they do not 'feel' the costs of pricing as strongly as people who do not receive any compensation. The possibility to work at home has the opposite effect. Respondents who are currently able to work at home intend to adjust a significantly higher number of car trips for commuting and 'other' trip purposes (see also Ubbels, 2006). People, who can work at home, may be less 'work place' constrained, making it easier to mitigate pricing costs when they are perceived to be too high. In addition, people who can work at home may be more flexible to make changes in other trips (for example, making shopping trips outside or in-between peak hours). With regard to social (visiting) trips, however, no significant effect occurs with respect to the possibility to work at home. This may be due to the fact that social trips are already often carried out (possibly with household members) in evenings and/or in weekends, making the influence of the possibility to work at home less influential for social trips. Moreover, the influences of the frequency of being confronted with traffic jams and the region in which the respondents live were tested. For social and other trips a quite similar picture emerged. Respondents who are often confronted with congestion (three times or more per week) indicated a relatively higher trip change intention. Such respondents might, for example, have the feeling to be worse off due to the measure because possible travel time benefits of the measure were not shown within the questionnaire. This might give them the feeling of having to pay more without benefiting through time gains. However, no significant influence of congestion severity was observed for commuting trips. Additionally, respondents living in a 'congestion sensitive' area in The Netherlands were found to have a higher intention to change commuting trips by car but on average indicated to have a lower intention than others to change their current social-related car trips. For 'other' car trips no clear sign was found.

In several models estimated for social and 'other' trips, the variable 'having children' proves to be significant. A negative effect emerges (in line with the results of Ubbels, 2006). People with children appear to have less room to change their existing travel behaviour. In the case of other trips, singles also have a lower trip change intention. An explanation for this finding may be that singles attach a higher value to all kinds of outdoor activities such as sports or going to the theatre since they do not have a partner or family at home, which makes them less willing to change their travel behaviour in this respect. Furthermore, car weight is often an important variable. For commuting trips, respondents with low or high car weights show a higher trip change than people with medium weight cars. Two effects might be interfering with each other. People with lighter cars on average may be more cost-sensitive than people with heavier cars, as we explained in section 5.3.6.2, and as a result may be more inclined to adapt their behaviour. Moreover, commuting trips on average are likely to be longer in distance than trips for social and other purposes. Also, the operating costs of heavier cars are often higher. High commuting distances (and higher costs), in combination with charging costs, may make respondents with heavier cars more inclined as well to change their behaviour than people with medium-sized cars. With regard to social and other kinds of trips, on the other hand, respondents with heavier cars indicated a relatively lower car trip change intention compared to cars with a lower weight. Larger families might have larger cars. In case of commuting trips the average car occupancy rate may well be lower than for social and other trips: people often go to work alone whereas, social and other kinds of trips are often made with family members or others. Because commuting trips are made alone more often, this may make it easier for people with larger cars to adjust car commute trips. Finally, we found that there is a positive relationship between a household having more than one car and a willingness to modify behaviour with regard to social trips. A possible explanation is that people who own more than one car try to minimise the use of the second car. However, we found no significant relationships between trip change and car availability for commuting or other kinds of trips.

5.4.2.2 – Differences between estimated models

The main differences in terms of the explanatory factors due to the type of trip purpose were already largely discussed in section 5.4.2.1. The current section focuses briefly on differences that emerge from more methodological and estimation-related reasons, i.e.: (i) the differences in results between models estimated with Poisson and Tobit regressions, (ii) the differences in results between the relative and absolute versions of the dependent variable and (iii) the differences that emerge when using a dataset containing all the respondents in the estimation process on the one hand, and using a dataset consisting of working people only.

As described in section 5.4.1, a sensitivity analysis was conducted in which a Tobit regression was estimated on the basis of the same model input characteristics (i.e. the same dependent and independent variables) as used in the Poisson regression model presented in Table 5.20. These results are shown in Appendix E. The general image that emerges is that when using Poisson regression (i.e. the absolute trip change), more significant influencing factors are observed compared to applying Tobit regression. This does not only appear to be the case for commuting trips (as is shown in Appendix E) but also for the visit and other motives. These sensitivity results are, however, not presented in Appendix E, as they did not add new insights compared to the sensitivity analysis for commute trips. Moreover, it appears that when factors are significant in both models, the sign of the explanatory variables is the same. The outcomes of the sensitivity analysis in Appendix E give an indication that the generally higher significance of coefficients when applying Poisson regression techniques may not particularly be due to a bias caused by using the absolute trip change as the dependent variable. One could argue, for example, that by using the absolute instead of the relative trip change variable, a bias occurs due to the fact that people who currently use their car more often are also able to 'change' more car trips due to road pricing. However, this would also assume that Tobit regressions estimated on the basis of the absolute trip change variable would lead to more significant parameter estimates than when using the relative trip change variable. As Appendix E shows, this is not clearly the case. In addition, the higher significance of Poisson regression coefficients has been found for all three trip motives (commuting, social visiting and other) whereas the variance in commuting trips that are to be changed is lower than the variance in intended changes in social and especially other car trips. Therefore, a more likely reason for the higher significance of many parameters in the case of using Poisson regression (in this situation) may be caused by the possible effect of 'overdispersion', which we already discussed in section 5.3.6.2. To control for this, a negative binomial model was also used as a sort of extra sensitivity analysis[112]. The results of this analysis indicated that the outcome of the negative binomial model to a large extent correspond to the Tobit regression results. This means that less significant effects are found compared to using the Poisson regression. However, the fact that the negative binomial results are in line with outcomes

112 This sensitivity analysis is not reported within this thesis.

of the Tobit regression, and since the sign of the coefficients does not change compared to using the Poisson regression, we feel that the results described in section 5.4.2.1 are valid.

At first sight the variables seem to be significant far less often when the relative rather than the absolute car trip change due to pricing is regarded. However, this is due in particular to the estimation technique we applied. As described above, when the dependent variable consists of relative trip changes (only) Tobit regressions are used. And it turned out that applying Poisson regression to the absolute trip change variable led to more significant independent variables. To study the sensitivity to the type of dependent variable without the type of estimation technique interfering with the results, a sensitivity analysis was carried out with the Tobit regression models estimated with the relative trip change variable as reference situation. For commuting this is model M2 (see Table 5.20) and for social and other trips model it is M3 (see and 5.22 respectively). The significant explanatory variables emerging in these models were also applied to estimate a Tobit regression model using the absolute trip change variable[113]. Utilizing this procedure showed us that the estimation results are relatively insensitive to using either the absolute or the relative trip change as the dependent variable in the estimation: (i) the sign of the coefficients remains the same, (ii) significance levels are in line and (iii) the relative strength of the coefficients rather stays the same.

As shown in figure 5.2, in the case of social and other trip purposes separate models were estimated on the basis of the full sample on the one hand, and on a sub-sample consisting only of working people on the other. Models estimated on the full sample show that respondents with a paid job indicated to have a significant lower intention to make changes in their current trip pattern. This may be due to higher time constraints workers face compared to non-workers. Working people may be less flexible when it comes to social and other kinds of trips. For example, they may have to do their shopping after working hours, whereas non-workers may be more flexible in choosing when to shop. The separate models estimated for both samples (i.e. all respondents and working people only) point out that in general the same explanatory variables are significant in both samples. Moreover, the coefficient signs are similar. However, a closer inspection reveals some small differences. It would appear that certain demographic factors, like education and gender, become less important when taking only working people into account. However, as may be expected, some specific work-related factors (e.g. travel cost compensation and the possibility to work at home) become more important when the sample contains only working people.

Overall, it can be concluded that the model results are sensitive to the type of statistical estimation technique that is being used. When applying Poisson regression analysis, more significant explanatory factors emerge compared to Tobit analysis. This difference was also observed in section 5.3.6, where the influence of price levels on trip change intention was studied via Poisson and Tobit regression analysis. Although the sensitivity to the statistical technique that is applied is high, the sensitivity to the shape of the dependent variable (absolute or relative trip change) and the sample size (i.e. all respondents or workers only) was found to be low.

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113 The exact estimation results from this sensitivity analysis are not shown in this thesis.

5.5 - Conclusions

The aim of this chapter was to gain insight into the extent to which (road) pricing policies influence the short-term trip pattern of households (thereby answering the first part of research question 3). More specifically, the chapter focused on different subtopics, the first of which focused on gaining insight into the share of car trips respondents intend to modify for commuting, social, other[114] and shopping trip purposes. The effects for the shopping purpose were distilled from a different dataset than was used with the other three motives. The second subtopic focused on the alternatives people preferred for their current car trips. Thirdly, differences in trip change behaviour between pricing measures and trip motives were examined. A fourth subtopic aimed at gaining insight into explanatory socio-economic, demographic and trip related factors with regard to trip change differences due to pricing.

Changes in current car trips for social (visiting) motives are higher than for commuting and 'other' purposes. On average (over the price measures), approximately 12 percent of the social car trips is changed, 10 percent of the trips for 'other' purposes and 9 percent for commuting. In the case of daily and non-daily shopping the percentage was the highest: approximately 19 percent. This is partly due to a cordon charge. The cordon charge in the sample leads to a higher relative change compared to a time-differentiated kilometre measure. The influence of a cordon charge measure was, however, not tested for the other three trip purposes. The higher inclination to change due to a cordon charge may have different reasons. The cordon charge we applied in this research is more spatially differentiated than the kilometre charges, which may offer people greater opportunities to avoid paying charging costs. Moreover, a cordon charge is fixed at a certain location. At that location a toll has to be paid at one instant. This might lead to a 'psychological threshold' for passing the toll point causing people to change their behaviour. Beside these charge-specific characteristics, the chosen price levels may also partly explain differences in trip change. The applied cordon charge for an average shopping trip may have been higher than the average charge that would have to be paid on the basis of a kilometre charge, leading to higher behavioural changes in the case of the cordon measure. When only the effects of the kilometre charges are compared, the percentages involving social, 'other' and daily shopping trips are quite in line. For non-daily shopping, on the other hand, a higher trip change is found.

Although average car trip change percentages are lowest for commuting trips, this does not mean that the 'aggregate' impacts of these changes on the overall traffic situation are also lower. On a four week basis, all the respondents in the survey together make 6800 commute trips by car, 3600 social car trips and approximately 7800 'other' car trips. Moreover, commuting trips are most often made during periods of high traffic demand (i.e. peak periods) and on average they are likely to be longer (i.e. in distance). All in all, this may well imply that the lower percentage of intended commuting car trip changes (compared to social and other trip changes) has a higher impact on travel times in traffic congestion 'sensitive' areas than changes with regard to social and 'other' car trips.

For commuting, the highest number of changes occurs as a result of time-differentiated charges: a time-differentiated kilometre charge (measure 3) and a fixed kilometre charge in combination

114 These refer to trip purposes other than commuting or social trips.

with a time-differentiated toll on bottlenecks (measure 2A). Furthermore, a time-differentiated kilometre charge (measure 3) and a flat kilometre charge (measure 1) lead to the highest car trip change percentages for trips with social and 'other' purposes. A striking effect is that the intention to change social and other trips due to a charge that is not time-differentiated (i.e. a flat kilometre charge or a kilometre charge differentiated according to car weight) is higher than the intention to change with regard to commuting trips. By contrast, for time-differentiated measures (2A and 3) the opposite is found: trip change intentions for social (visiting) and other trips are lower compared to commuting. A possible explanation is that travelling at other times is less interesting when it comes to non-commuting trips, as these trips are often made outside peak periods anyway. Overall, a kilometre charge differentiated according to car weight (measure 2B) leads to the lowest car trip change and thus can be seen as the least effective approach to solving traffic congestion.

Focusing on the alternatives that are chosen, 'travelling at other times' is the most popular option for the time-differentiated measures (2A and 3); in the case of commuting, public transport is the second most selected alternative. For social and 'other' trips by car, however, slow traffic (instead of public transport) was chosen more frequently. This may be due to an on average higher commute trip length relative to the average distance for social (visiting) related or other trips, which makes slow traffic more interesting for non-commute trips. For the measures that are not time-differentiated (1 and 2B), slow traffic is selected most frequently for all purposes. In the case of the social and 'other' categories, not making the trip at all is the second favourite option after slow traffic. For commuting trips this is not an interesting alternative, possibly because these trips offer less flexibility and cannot be avoided. Two additional findings need to be mentioned here. First of all, the percentages for public transport are relatively stable over all measures and trip motives. Secondly, 'work at home' is the option that in general was selected the least often.

Preferred alternatives for current shopping trips by car are quite comparable to 'popular' alternatives for social (visiting) and other trips by car. The only big difference arises for the option 'travel at other times'. This option is chosen less often as an alternative for current shopping trips by car. We found that most people do their shopping outside peak hours anyway. This may explain the lower interest in changing departure times. Unfortunately, information regarding the timing was not available for commuting, social and other trips. This makes the difference in popularity of the alternative 'travel at other times' hard to explain. In the case of shopping trips respondents could also change their shopping location. This option was regularly chosen, particularly with regard to non-daily shopping in another city: around 20 percent of the car trips to be adjusted are diverted to a different location. The location change option was formulated as 'doing shopping x-times per time period[115] more often by car closer to home' in the case of the kilometre charge, and as 'doing shopping x-times per time period more often by car closer to home or in another city without a charge' in the case of the cordon measure.

In addition to insight into trip frequency changes and interesting alternatives for car trips, the influence of toll costs (i.e. the height of the charge) and the type of revenue use was analyzed. The general effect of price is that respondents, who have to pay higher charges, indicate relatively higher car trip changes. However, for shopping trips no significant effects of price occurred at all.

115 For daily shopping a time period of one week was used; for non-daily shopping a one year period was applied.

This may to a large extent be explained by the relatively low sample sizes in the 'shopping survey'. Only two revenue uses were presented to the respondents: 'reduction/abolition of fixed car taxes' and 'reduction of income taxes'. Respondents who were presented with the first option indicate they are less inclined (albeit not always significantly so) to change their behaviour. This may be due to the specific traffic-related benefits in the case of the first type of revenue use, but it may also be explained by the fact that explicit cost benefits were presented to respondents for the first option and not for the revenue use 'lowering income taxes' (also see section 5.3.1).

Some regularities with respect to the influence of price levels were found. Price effects[116] are often significant in the case of the flat kilometre charge (price measure 1). For the kilometre charge based on car weight (2B), however, almost no significant influence of price height was found. For the time-differentiated measures (2A and 3), price difference influences are also statistically significant less regularly. Moreover, for social and other trip purposes there were nearly no significant price[117]effects due to time-differentiated measures (measures 2A and 3). Looking at the type of price variable that results in most statistically significant effects, it can be concluded that, on average, the variables 'total annual charge costs' and 'total annual costs' are more explanatory for trip change than the price level (charge/km). Respondents seem to base trip change decisions more on total annual costs than on the price per kilometre, possibly because the annual costs are more informative. Nevertheless, differences in trip change intentions due to different price levels are often not significant, even in the case of annual (toll) costs. Due to the distribution of the dependent variables for car trip change, some sensitivity analyses were carried out through analytical techniques like Tobit and Poisson regression analyses, to study whether further significant price effects could be found (see section 5.3.1 for a detailed motivation of our use of these techniques). Although Poisson regression results indicated some more significant price level effects compared to ANOVA-analyses, t-tests and Tobit regressions, in general the differences appeared to be small.

In all situations, the influence of price was tested for two different dependent variables: the absolute and the relative trip change. No systematic differences in the influence of price for using both dependent variables were found. Sometimes the absolute and sometimes the relative form of the dependent variable leads to higher significance levels. But, in most cases results match.

Overall, it can be concluded that the highest car trip changes occur for non-commuting trips. With respect to the pricing measures, the time-differentiated kilometre charge (measure 3) is most effective in changing people's current car trips. The kilometre charge plus an additional time-dependent bottleneck toll measure (2A) comes in second place when commuting trips are considered. The flat kilometre charge (measure 1) is more effective in changing with regard to the social and 'other' categories than it is for commuting. Overall, the kilometre charge based on car weight (measure 2B) leads to the lowest number of trip changes. For shopping the highest car trip change was found to occur due to a cordon charge. Furthermore, studying the influence of price height on trip change showed that, generally speaking, higher charges lead to more changes in people's behaviour. However, price effects are often statistically insignificant. Finally, a more

116 Charge/km, total annual charge costs and total annual costs (charge costs – benefits).

117 Price effects are tested for three variables here: charge/km, total annual charge costs and total annual costs (= charge costs – benefits).

traffic-related revenue use, in which the benefits are expressed in costs, seems to result in lower trip change intentions compared to more general types of revenue use, such as lowering income taxes.

In addition to examining the influence of price and revenue use, we also looked at the impact of socio-economic, demographic and trip related factors. The most important explanatory factors are household income, travel cost compensation, the number of kilometres driven per year and the education level. A higher income leads to a lower trip change intention. The same goes for respondents who receive a travel cost compensation. Furthermore, respondents who drive more kilometres proved to have a higher trip change intention. With regard to education a more mixed result was found. Respondents with a higher education level relatively have a higher intention to change commute trips or other kinds of trips. However, by comparison, they are less inclined to do the same when it comes to social trips.

One thing we were unfortunately unable to include explicitly in this study is the impact possible travel time benefits resulting from road pricing measures have on behavioural changes. We simply did not have the time or money available to examine this. However, Appendix D, in which the results of an analysis into the influence of travel time gains on respondents' perceptions of being better or worse off due to road pricing are presented, offers some indication that commuters are rather insensitive to the size of time benefits. As we will show in chapter 7, firms tend to respond more positively to suggestions that changes in their trip behaviour may lead to time benefits. On the whole, it is difficult to say what effects the benefits have on people's behaviour. However, it may be worthwhile to take a closer look at the way time benefits affect people's (short-term) behaviour in further research.

Whereas this chapter provided insight into changes in the trip pattern due to different price measures, chapter 6 focuses on longer-term changes. Longer-term changes are thereby operationalized as changes in the residential and/or working location of households. These longer-term effects are also studied on the basis of household questionnaire 2.

6 - Road pricing and residential and work location decisions households

6.1 - Introduction

Chapter 5 focused on the short-term reactions to pricing measures, providing an answer to the first part of research question 3. This chapter focuses on the longer-term (re)location effects of households and tries to answer the second part of research question 3, which is printed in bold below.

To what extent do (road) pricing policies influence short-term trip/travel patterns and **(re)location, especially work and residential location, choices of households?**

Two phases can be distinguished within the relocation process: (i) the choice to relocate and (ii) the search process and final choice where to locate (see also section 2.6.3.2). The influence of (road) pricing on both phases is described in this chapter. More specifically, on the one hand the influence of different (road) pricing measures on the probability to change the residential and/or work location is examined. Additionally, influential socio-economic, demographic and trip-related factors with regard to people changing locations due to pricing are studied. On the other hand, with respect to the final choice of location, this chapter provides insight into the influence of toll costs relative to travel time and more location-related factors in the final decision where to locate.

The outline of this chapter is as follows. Section 6.2 briefly addresses the two phases in the relocation process: the decision to relocate and the choice of location. Subsequently, section 6.3 focuses on the influence of different pricing measures on the relocation probability. Part of this section is attributed to analyzing which types of households to a greater or lesser extent intend to change their residential or work location due to pricing measures. Section 6.4 examines the importance of toll costs compared to other travel and location-related variables in the selection of a new residence (location). The conclusions are presented in section 6.5.

6.2 - Two stages in the relocation decision

Central to our approach in this chapter is the observation that relocation decisions consist of various stages (Rossi, 1955; Moore, 1972; Vickerman, 1984; Weinburg, 1979; Devisch, 2005). Wong (2002) formulates a conceptual model with two major stages within the relocation process: (i) the decision to move and (ii) the selection of a new residence. These two major stages of the housing decision tree are likely to be interdependent and linked. As we described in section 2.6.3.2, the decision to move in relation to the residential location can have various causes (see, for example Clark, 1982; Dieleman, 2001; Wong, 2002), which may be related to changes in the (lifestyle of the) household (household composition, income or changes in preferences) but also to external

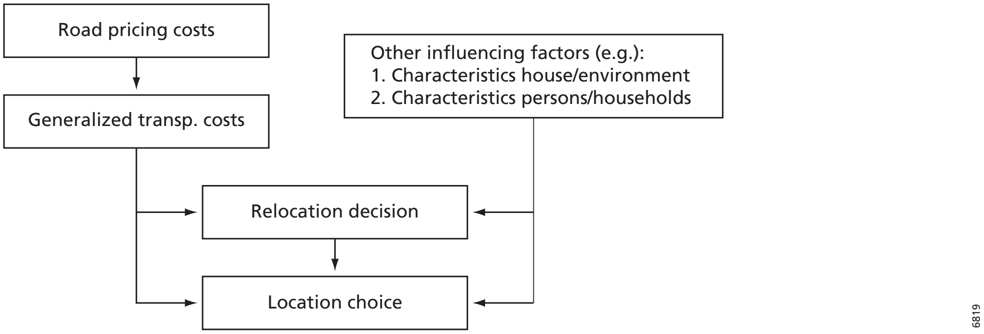

Figure 6.1: road pricing and (re)location choice

factors, such as changes in the environment (e.g. socio-economic status of the neighbourhood). In addition, there are various reasons why people may be looking for a new job, such as moving to another residential location but also changes in job satisfaction and in household lifestyle (for example getting children which will lead to higher time constraints). Moreover, the introduction of (road) pricing can be seen as an external trigger for people to 'wake up' as well. In particular, it may motivate people to look for an alternative place to work or live in the case the generalised travel costs change to such an extent that a 'stress threshold level' is exceeded (Wong, 2002). Generalized transport costs may become too high for a household leading to the decision to relocate in order to decrease average travel costs to one or more (important) activity locations. On the other hand relocations might also be initiated by travel cost decreases. If a price measure for example leads to travel time benefits, a household might decide to relocate to a more preferred location, which has become accessible (in reach) due to the time benefits.

Once the decision to relocate has been made, a household will engage in a search for a new job or place to live that better matches its preferences on a number of criteria, including characteristics of the house/job and the general environment, but also the expected (generalized) travel costs, which are affected by road pricing policies (see figure 6.1). The general effect of (especially commuting-related) travel distance, time or cost on location decisions (see, for example, Brown and Moore, 1970; Gera and Kuhn, 1980; Weisbrod *et al.*, 1980; Zax & Kain, 1991; Van Ommeren *et al.*, 1997; Van Ommeren *et al.*, 1999; Rouwendal and Meijer, 2001; Clark *et al.*, 2003) suggests that road pricing will be an important factor in the location decision.

Road pricing may play a role in both stages of the relocation process: the decision whether or not to relocate and the choice of the new living or working location. Even when a household chooses to relocate for another reason, road pricing may still influence the decision where to locate. Moreover, road pricing can also influence the initial decision to relocate[118].

118 For example it can influence the location decision of persons moving out of the parental house.

6.3 - Residential and work relocation decisions of households

6.3.1 - Introduction

This section focuses only on the first stage, i.e. the choice to relocate (see figure 6.1). The objectives of this section are twofold. The first aim is to gain insight into the probability of households changing their home and/or job location due to different types of (road) pricing measures. The second goal is to learn more about the explanatory variables (for example, which groups are more or less willing to relocate) for relocating due to road pricing. To get this insight different models are estimated for the type of relocation (i.e. residential and work relocation) and the type of measure (i.e. a kilometre charge and a cordon charge). Additionally, the sensitivity of the results to the modelling approach used is studied implicitly (see section 6.3.4.1 for a further explanation). At this stage it is good to note that road pricing is also likely to affect the spatial distribution of demand for houses, which in turn will affect housing prices in certain areas. Although such effects may in themselves have a secondary effect on location patterns they are not included in this study; the focus is on the primary effect of road pricing on relocation decisions (see also chapter 1, section 1.3).

Before presenting the results, in section 6.3.2 we describe the main characteristics of the data we have used. Section 6.3.3 analyses the probabilities of households changing their current residential or work location due to a pricing measure. Section 6.3.4 examines the influencing characteristics (especially socio-economic, demographic and trip-related) for relocating due to pricing measures. Finally, section 6.3.5 focuses on the extent to which the results can be transferred to the Dutch working population as a whole.

6.3.2 - Data characteristics

The relocation probabilities due to pricing measures are studied on the basis of the dataset of household questionnaire 2. This is the same dataset we used to gain insight into the trip behavioural effects in chapter 5. Although the general characteristics of questionnaire 2 were discussed at length in sections 3.4.4 and 5.2, for the reader's convenience we present a brief outline here, bearing in mind that in this section the emphasis is on the relocation-related questions within the questionnaire.

The survey was held among 562 respondents. Only employed respondents (in total 465) were asked to indicate the probability of relocating due to a road pricing measure. 284 of them were commuters who drive to work by car twice or more per week and face congestion of 10 minutes or more per trip at least twice a week. We selected car commuters because they in particular face congestion problems on a regular basis and thus are directly affected by pricing measures aimed at reducing congestion (see also section 3.4.2 for a more elaborate overview). The other 181 respondents were working people who owned a car (within their household)[119]. They were added to broaden the scope of the study and also to study the (behavioural) effects as a result of pricing measures for other groups than regular car commuters (in congestion) (see section 3.4.4). Each respondent was presented with three different kilometre charges (see section 3.4.4, Table 3.5 for

119 In fact 274 respondents within the total dataset were selected on the basis of the criterion of household car possession. Because only working people were asked to indicate the probability that they would relocate, the 181 remaining respondents are working people owning a car (in the household).

a complete overview). The respondents were asked to indicate the probability that they would relocate to another house (closer to work) or look for another job (closer to home) on a 7-point Likert-scale ranging from 'highly unlikely' to 'highly likely'. Additionally, working respondents driving to work by car at least once a week, living and/or working in a medium-sized or large city and leaving the city boundary at least once at every car commute trip were presented with a cordon charge. In total 262 respondents met these requirements, 195 of them belonging to the group of drivers who regular faced congestion, and the remaining 67 falling into the category of working people who own a car. Thus, three kilometre charges were presented to 465 and two cordon charges to 262 respondents (of the 465). Each of the five measures included different alternatives, which were randomly assigned to the respondents. The measures are presented in detail in Table 3.5 (chapter 3, section 3.4.4). Measures 1 to 3 are kilometre charges, measures 4 and 5 are cordon charges.

Although varying short-term and long-term behavioural effects and attitudes were determined for the three kilometre charges within the survey, for budgetary reasons and to avoid overburdening the respondents, we limited the size of the questionnaire. Therefore, in the case of the cordon charge, questions were limited to relocation and one acceptance question. This also means that in analysing explanatory variables for relocation due to a cordon charge (see section 6.3.4), the influence of different attitudes towards cordon pricing and the effect of short-term behavioural changes on the relocation probability due to a cordon charge could not be investigated.

6.3.3 - Relocation probability of households

As noted previously, long-term responses to road pricing measures include both residential and workplace relocations. Table 6.1 shows the distribution across probability categories of people changing their residential location due to different price measures. Furthermore, the sums of the categories (5 to 7 and 6 to 7) representing the highest probabilities are shown. The average percentage of respondents (taken over all measures) who reported that the likelihood that they would move house is 'quite high', 'high' or 'extremely high', is 5.2 percent. 2.9 percent indicated that that probability is 'high' or 'extremely high'. The probability is highest in the case of the

Table 6.1: probability of moving house by type of measure

Probability of moving house (%)	M1 flat km charge	M2 km charge + toll or km charge weight car	M3 time-dependent km charge	M4 cordon charge (5€)	M5 cordon charge (8€)
1: Extremely low	72.5	70.8	65.4	62.2	63.7
2: Low	18.9	19.4	24.3	23.3	23.3
3: Quite low	1.9	2.6	3.0	4.2	2.3
4: Not low/high	2.4	3.4	3.4	3.1	4.2
5: Quite high	2.2	2.2	1.5	3.4	2.3
6: High	1.1	1.1	1.9	3.1	1.9
7: Extremely high	1.1	0.6	0.4	0.8	2.3
Sum 5 to 7: quite to extremely high	4.3	3.9	3.8	7.3	6.5
Sum 6 to 7: (extremely) high	2.2	1.7	2.3	3.9	4.2

Table 6.2: probability of searching for another job by type of measure

Probability of searching another job (%)	M1 flat km charge	M2 km charge + toll or km charge weight car	M3 time-dependent km charge	M4 cordon charge (5€)	M5 cordon charge (8€)
1: Extremely low	57.0	60.9	57.8	49.2	52.3
2: Low	22.8	21.3	22.8	24.0	19.1
3: Quite low	3.7	3.4	3.2	4.6	4.6
4: Not low/high	5.8	4.7	4.5	6.1	7.3
5: Quite high	6.0	5.2	5.2	6.9	6.1
6: High	3.0	3.7	4.9	7.3	7.3
7: Extremely high	1.7	0.9	1.5	1.9	3.4
Sum 5 to 7: quite to extremely high	10.7	9.8	11.6	16.1	16.5
Sum 6 to 7: (extremely) high	4.7	4.6	6.4	9.2	10.7

cordon charges (i.e. M4 and M5). This seems in line with the expectation that a more spatially differentiated charge (in this case the cordon charge) leads to higher relocation probabilities, because the impact of a toll charge increases spatial contrast. As mentioned in section 6.3.2, however, only respondents living and/or working in a medium-sized/large city (at least 40,000 inhabitants), who are likely to cross a cordon, answered the cordon-related relocation questions, which may lead to an overestimation of the share of commuters considering relocation (in comparison to the kilometre charge results). Additionally, around 10 percent of the respondents in the case of the kilometre charges indicated they did not drive to work by car. Respondents answering cordon charge-related questions, on the other hand, drive to work at least once a week, which probably leads to a higher inclination to relocate compared to the kilometre charges.

The probability results with regard to looking for another job are presented in Table 6.2. This probability is significantly higher ($\alpha \leq 0.05$) than the probability of people moving house. Averaged over the measures, 12.9 percent of the respondents indicated that the probability is 'quite high', 'high' or 'extremely high', and 7.1 percent reported a 'high' to 'extremely high' probability.

To put these results in a proper perspective, the probabilities of moving houses or changing jobs were also calculated depending on whether people were considering relocating anyway, regardless of the introduction of road pricing. It turned out that a road pricing measure makes it even more likely that people who wanted to move anyway will actually do so. For kilometre charges this 'connection' is stronger than for cordon charges. As an illustration, the results for the kilometre charge are shown in Table 6.3. Thus, especially respondents who are already planning to relocate are expected to be influenced in their relocation decision by a road pricing measure. Nevertheless, there are still a number of respondents that reported a high probability of changing locations and did not consider relocation in the situation without road pricing. Moreover, there is a significant relationship between changing the residential or work location due to (road) pricing. However, the majority of respondents who indicated to relocate due to pricing chose to adapt only one location (either the job or residential location).

Table 6.3: probability moving house or job due to one of the three kilometre charges relative to intention to move anyway (left table: moving house; right table: moving job). The numbers indicate the number of choices (not the number of respondents); one respondent occurs three times within the results.

Cross tabulation	**Prob. move house within 2 years (moderately, high, very high =1)**			
Prob. move house due to road pricing (quite high, high, very high =1)		0	1	Total
	0	1044 98.9 %	295 87.0 %	1339 96.0 %
	1	12 1.1 %	44 13.0 %	56 4.0 %
	Total	1056 75.7 %	339 24.3 %	1395
			Value	P-value
	X^2		93.4	0.000
	Kendall's tau-b		0.259	0.000

Cross tabulation	**Prob. change job within 2 years (moderately, high, very high =1)**			
Prob. search another job due to pricing (quite high, high, very high =1)		0	1	Total
	0	935 96.2 %	311 73.5 %	1246 89.3 %
	1	37 3.8 %	112 26.5 %	149 10.7 %
	Total	972 69.7 %	423 30.3 %	1395
			Value	P-value
	X^2		158.8	0.000
	Kendall's tau-b		0.337	0.000

In chapter 2 (i.e. section 2.7) we described two studies that also tried to gain insight into the relocation probability/intention of people as a result of (road) pricing measures. One of these studies, MuConsult (2000), estimated[120] the percentage of people who would relocate due to a pricing measure. The reported percentages are in the range of one to seven percent. With respect to the kilometre charge, MuConsult expects that the percentage will be higher with regard to job change than with regard to residential change. For a toll-based charge[121] a higher residential change is anticipated. No explanation is given for this difference. This in itself is not strange because the relocation percentages vary only slightly.

Arentze and Timmermans (2005) studied the relocation intention of Dutch households on the basis of a stated adaptation experiment. The road pricing scenario used consisted of a time-differentiated kilometre charge with a higher price level in the peak period. Different price levels were used. For the off-peak period charge levels of seven and nine Dutch guilder cents per kilometre were used (i.e. respectively 3.2 and 4.1 eurocents/kilometre). For the peak charge 15 or 20 guilder cents were added to the off-peak charge (i.e. an extra charge of 6.8 or 9.1 euro cents respectively). This makes the charge quite comparable to the average price level in the time-differentiated kilometre charges applied in this thesis (see price measure 3B and 3E in section 3.4.4, Table 3.5). Arentze and Timmermans (2005) found that 88.2 percent of the respondents would not consider a change, 2.0 percent would change their work location and 11.1 percent would change their residential location.

Overall, it can be concluded that the results presented in the studies of MuConsult (2000) and Arentze and Timmermans (2005) are more or less of the same size as the results presented here. Unfortunately, the results can only be compared very roughly because of likely sample differences

120 These estimates are based among other things on elasticities.

121 More specifically, the Dutch Rekeningrijden proposal by minister Netelenbos of the Ministry of Transport, Public Works and Water Management in the cabinet Kok-II (1998-2002) was used.

but also due to the fact that the dependent variables are different. The results reported in Tables 6.1 and 6.2 focus on the probability that people will change their location, whereas MuConsult used the formulation of 'residential change percentage' and Arentze and Timmermans asked respondents about their intention to relocate. Such differences in the (formulation of the) dependent variable may influence 'relocation results' to quite a large extent (see also Tillema *et al.*, 2004). Although the process of comparing results must be undertaken with some care, at least a striking difference is that Arentze and Timmermans find a substantially higher residential compared to job location change, whereas on basis of household questionnaire 2 the opposite emerged: a higher job compared to a residential relocation. A clear explanation for the difference cannot be given.

It is important to note that the results described above are retrieved from the sample of household questionnaire 2. Although in themselves the relocation probabilities are insightful, it may also be interesting (e.g. from a policy point of view) to see to what extent the results can be transferred to a certain (more general) population. Because the residential as well as working relocation probabilities are studied, it may be useful to focus on the transferability of the (sample) results to the Dutch working population. To do so, the differences between sample and population characteristics have to be assessed. These differences and their implications for the relocation probability results, described above, are examined in two ways. First, in this section the transferability of the relocation probability results is examined briefly by looking at the differences between the population and the sample on the basis of the sample selection characteristics, i.e.: (i) facing congestion regularly or (ii) having a car within the household. Secondly, section 6.3.5 examines the transferability of the results on the basis of significant explanatory variables (especially the socio-economic and demographic ones) in section 6.3.4. The applied technique in section 6.3.5 is called sample enumeration.

As described in section 6.3.2, in one part of the sample respondents were selected who face delays of 10 minutes or more per trip at least twice a week. This selection criterion quite likely leads to an overestimation of 'congestion' car drivers in the sample compared to the overall Dutch working population, first of all, because not all Dutch workers live and/or work in congested areas, and secondly, because not all commuters go to their work by car. For the average Dutch working population no results with regard to the frequency of facing congestion problems were found. However, the expectation is that the frequency is lower compared to what we found in the sample. It is hard to determine whether people who regularly face traffic congestion have a higher or lower relocation probability due to pricing. On the one hand, road pricing measures may reduce travel times, possible making congestion drivers better off compared to the current situation. On the other hand, financial travel costs may rise due to the pricing measure, affecting especially congestion drivers (assuming there are no travel time benefits), which may make them more willing to relocate than people who face congestion problems less often. Sections 6.3.4 and 6.3.5 focus on the relationship between how often people face traffic congestion and the probability that they will relocate.

The selection criterion for the second type of respondents that were added to the congestion driver sample, was that there had to be at least one car within the household. This means that every household included in the sample owned a car[122]. In all, 77 percent of all Dutch households owns a car (CBS, 2005). Households that do not own a car are very unlikely to change their trip behaviour due to the introduction of a (road) pricing measure, which implies that the relocation probabilities presented in the beginning of this section may be an overestimation. However, the focus here is specifically on transferability to the Dutch working population. Although no information regarding the level of car ownership level among working households is available, there is data available regarding the percentage of individual workers who own a car (CBS, 2005). On the basis of the average number of individuals per household, a rough estimate can be made regarding the average number of cars per 'working' household. The resulting number of cars per household with at least one worker, i.e. 1.5 cars, is in line with the results in the sample. On the basis of these results the expectation is that the car ownership level for the sample and the working population are similar.

In short, with respect to car ownership, no major differences are expected between the sample and the overall working population, which implies that the results are transferable. On the other hand, because it is not clear what the relationship is between 'facing congestion regularly' and the probability of people relocating, it cannot be concluded here whether or not the sample over- or underestimates the relocation probability. Section 6.3.5 will focus on the transferability issue into more detail taking results from section 6.3.4, concerning the explanatory factors for relocation due to pricing, into account.

Before moving on to the next section, in which we examine the influencing (especially socio-economic and demographic) factors for the decision to relocate, two additional comments have to be made, one with respect to the transferability of the results to other countries and the other related to housing prices. The results presented here are obtained on the basis of data collected in the Netherlands. In other countries the costs of relocation (for instance with regard to taxes) may be different from those that apply to the Netherlands, which may affect the likelihood that people may relocate as a result of road pricing measures. In addition, for the sake of convenience, we did not take possible changes in house prices as a result of road pricing measures into account. As such, we may assume that people answered the questions we posed them based on the implicit assumption that house prices would not be affected, although in reality road pricing measures may affect house prices which may have an impact on the probability of people relocating as a result of those measures.

6.3.4 - Influencing factors for the decision to relocate and the sensitivity of the results

6.3.4.1 – Introduction and methodology

To gain insight into the factors that affect the decision to move house or job, ordered probit models (see Greene, 2002; Train, 2003) were estimated in which the probability of relocating (in response to a charge), expressed on a 7-point Likert-scale, serves as the dependent variable. At first sight it may seem strange to try and gain insight into factors explaining the (differences in) relocation probability, keeping in mind the low levels of probability with regard to people's

122 Because the selection criterion for the first sub-sample was that respondents had to face traffic congestion while they commute by car at least twice a week (with a minimum of 10 minutes), one may assume they also own a car.

working relocation, and especially their residential relocation (see Tables 6.1 and 6.2). However, from a statistical point of view it can be done since respondents indicated their relocation probability on a fairly broad ordinal scale (7 classes). The estimation procedure not only takes into account the respondents who are likely to relocate but uses the entire distribution of answers across the seven categories. Nevertheless, although one can defend estimating a model, it must be emphasized that the estimation results will be based in particular on (the differences between) categories containing a substantially high number of cases (i.e. in this case especially the classes representing a relatively lower probability of relocating). Because the higher classes contain relatively few observations, which may influence the estimation procedure (see above), the seven classes were aggregated into four major categories: (i) an extremely small probability, (ii) a low probability, (iii) a rather low and neither low nor high probability, (iv) a rather high, high or extremely high probability. No analysis was conducted to gain insight into the sensitivity (of the results) to using a dependent variable with either seven or four classes. With respect to the firm relocation probability reported in chapter 7 (section 7.5), however, such a sensitivity analysis was indeed carried out. This analysis (section 7.5.3) showed that results (i.e. explanatory factors and their significance) vary only marginally, which implies that clustering categories may hardly affect the results, which in turn means that it may not have been necessary to cluster the categories in the first place.

Different models were estimated. In the first place a distinction was drawn between estimating job relocation and residential relocation, based on the expectation that there are (some) dissimilarities in the factors explaining the differences in the relocation probability due to a pricing measure: job relocations and residential relocations are different types of relocations that may have possibly different underlying explanatory characteristics. Also, the job-related and residential relocation probabilities reported in section 6.3.3 are clearly different, which may indicate that people may perceive the two types of relocation differently: people are more likely to change jobs than they are to move house. Section 6.3.3 reported that a large part of the respondents did not have a high probability of changing both types of locations (i.e. job and residence). Thus, some respondents are more inclined to change their residential, while others have a higher intention to change their working location, which may indicate there are potential differences with regard to the factors explaining the relocation probability due to pricing. However, although a large part of the respondents did not have a high probability of changing both types of locations, a significant relation between job location and residential location change was found (section 6.3.3). This may imply that the intention to change one type of location due to a pricing measure may also influence the intention to change another type of location. Therefore, we decided to include job relocation as an explanatory variable for residential relocation change and vice versa, but not to estimate a combined model for both types of relocation.

In addition, looking at the type of road pricing measure and relocation, two separate models were applied, one for the combination of all three kilometre charges (measures 1 to 3, see chapter 3, section 3.4.4, Table 3.5) and one for the combined cordon measures (measures 4 and 5). The reason for estimating separate models for the relocation probability due to a kilometre and a cordon charge is that, as described in section 6.3.3, the relocation probabilities for both types of measures are significantly different: the cordon charge leads to higher relocation probabilities, presumably because a cordon toll is more spatially differentiated than a kilometre charge. Subsequently, the responses to the three kilometre charge measures were combined in a single model because these relocation probabilities are comparable (see section 6.3.3). The same goes for the relative probabilities due to the two cordon charge measures. However, by including dummy variables for each price measure within the estimation, possible relocation differences between the separate measures could still be tested. Anticipating on the results, these 'measure-specific dummy variables' were not found to be significant explanatory. For that reason they were not included in the final model estimations presented in section 6.3.4.2. This would appear to indicate that explanatory variables, their coefficients and the explanatory significance would not have been very different had the models been estimated for each price measure separately. Nevertheless, this remains somewhat speculative, as it was not actually tested. Still, it must be emphasized that the results (e.g. explanatory factors and their significance) for the combined models (i.e. combining results on three kilometre charges on the one and the two cordon charges on the other hand) are likely to be slightly different than if the individual explanatory models with regard to relocation had been estimated separately.

To estimate the sensitivity of the model outcomes several sensitivity analyses were carried out with respect to the sample characteristics and the modelling approach we used. As described in section 6.3.3, the likelihood of people moving house or changing jobs in response to road pricing is significantly higher for people considering such a move anyway. To focus on the explanatory factors with regard to location changes that are specifically initiated by road pricing measures, it may be worthwhile to remove respondents who indicated a high possibility of changing location within 2 years anyway from the dataset. However, because this reduces the size of the sample, separate models were constructed, on the one hand for the larger sample containing respondents who are likely to relocate (within the foreseeable future) for whatever reason and, on the other hand, for a sample in which these respondents[123] were not included.

In addition, some models other than 'standard' ordered probit were estimated, for two reasons. First of all, the ordered probit model assumes a normal distribution of the unobserved factor of the model (i.e. ε). The distribution of ε determines the probability of the responses. However, the data is not evenly distributed among the four (aggregated) response categories. The distribution is skewed. The first two classes (i.e. (i) an extremely small probability, (ii) a small probability) contain more observations than the higher two classes. Therefore, a sensitivity analysis was conducted using the extreme value (or complementary log log) distribution, which leads to an asymmetric distribution with a skew to the right (possibly fitting the data better). The second reason for using an extension to the base ordered probit model has to do with the fact that some respondents were presented with various charges. In the case of the kilometre charge one respondent was presented with three different charges (one randomly assigned measure per kilometre charge alternative), while another respondent was presented with two cordon charges. This 'repeated choice problem' may result in correlations in response probabilities because of non-independent choices: a person who indicates a high chance of moving due to a charge may also feel a relatively high intention to change location due to another charge. This possible correlation was accounted for by estimating

123 In the case of estimating the residential relocation probability due to road pricing only respondents were removed who are quite likely to change their residential location within two years anyway. Not removed in this case are those having a high chance of changing job within 2 years. For estimating the work location change probability the opposite approach has been applied, i.e. only skipping respondents with a high probability of changing job within two years.

random parameter ordered choice models, correcting for repeated choices (i.e. three choices per individual). The random parameter ordered choice model is suitable for estimating models on the basis of panel data. Panel data are data in which observations are collected at different points in time. In this case the repeated choices made by a respondent can more or less be regarded as being choices made at different points in time. It must be noted that although the random parameter model is suitable for estimating a model with repeated choices, somewhat different coefficient values (and significance levels) are likely to be found when different models would be estimated for each of the pricing measures separately (see above). For a description of random parameter ordered choice models, including the (general) equations, see chapter 3, section 3.5.3. The sensitivity to the type of distribution and to the occurrence of repeated choices is only assessed for the kilometre charge measures, because of the higher sample sizes (compared to cordon charges). In addition, tabulated sensitivity results are provided for job relocation only.

Various explanatory variables (i.e. socio-economic, trip and price measure related characteristics, attitudes and perceptions) were tested. The explanatory power of the different variables was first tested separately, after which single significant variables (in general $\alpha \leq 0.10$) were taken into account in a 'combined' model estimation with all other significant variables. From this model new non-significant variables were excluded until only variables remained that were significant with a reliability of at least 90 percent ($\alpha \leq 0.10$), with the exception of variables that appeared to be logical explanatory variables ($\alpha \leq 0.15$). In the following subsections the model results are described. Section 6.3.4.2 focuses on important influencing factors for the residential relocation probability. In addition, section 6.3.4.3 looks specifically at the results with regard to job relocation and describes the explanatory factors, while at the same time comparing them with the results for the residential relocation probability. Section 6.3.4.4 summarizes the main findings, specifically concerning the differences in explanatory factors between residential relocation and job relocation and between the kilometre charges and cordon charges. Section 6.3.4.5 finally, elaborates on the sensitivity of the results for (i) the sample size used (i.e. in/exclusion of respondents who are likely to move anyway) (ii) the distribution of the error term (i.e. normal versus extreme value (Weibull) distribution) and (iii) the sensitivity with respect to correcting for repeated choices made by the same individual.

6.3.4.2 - Influencing factors for residential relocations

Table 6.4 presents the results of the ordered probit analyses concerning factors that influence the residential relocation probability due to transport pricing measures. The left part of the table contains the outcomes for the kilometre charge measures (i.e. M1 and M2). The right part resembles the cordon charge results (i.e. M3 and M4). In addition, the left columns for the kilometre and the cordon charge (i.e. M1 and M3) represent the results estimated on the full sample. Estimations presented in the right columns (i.e. M2 and M4) where made on a sample from which respondents were removed who indicated they were likely to move house within two years anyway. Within Table 6.4, a distinction is made between influencing factors that can be categorized as 'personal, work and trip-related characteristics' and variables that are labelled as 'perceptions and behavioural changes'.

With respect to the 'personal, work and trip-related characteristics', several significant factors for both the kilometre and cordon charge emerge. All these factors are relatively influential. The variable *changing house within two years* (in model M1 and M3) has the strongest influence on

Table 6.4: Influencing variables for residential relocation probability under influence of a kilometre of cordon charge (ordered probit estimations)

Change residential location (closer to work)	**Km charge 1,2,3**				**Cordon charge**			
	M1: ordered probit		**M2: removal high house probability change 2 yr**		**M3: ordered probit**		**M4: removal high house probability change 2 yr**	
	Coefficient	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**
Constant	-0.4972	0.0136	-0.6940	0.0001	-0.8479	0.0273	-0.8249	0.0002
Personal, work and trip-related characteristics								
dummy age respondent (≥40 years = 1)	-	-	-0.1901	0.0450	-	-	-	-
dummy annual gross household income (<28,500 euro=1)	-	-	0.3604	0.0036	-	-	0.5517	0.0018
dummy annual gross household income (>68,000 euro=1)	-	-	-	-	-	-	-	-
dummy education (high school, college, university=1)	-0.1779	0.0351	-0.2639	0.0084	-0.2774	0.0737	-	-
dummy working partner (yes=1)	-	-	-	-	-	-	-	-
dummy having child(ren) (yes=1)	0.1951	0.0148	0.2481	0.0094	-	-	0.2729	0.0487
dummy owned house (bought=1)	-0.1574	0.0698	-	-	-	-	-0.3217	0.0346
dummy car medium weight (yes=1)	-	-	0.2240	0.0174	-	-	-	-
dummy heavy car (yes=1)	-	-	-	-	-0.2975	0.0603	-	-
dummy gasoline car (yes=1)	-0.2059	0.0226	-0.4587	0.0000	0.4738	0.0053	-	-
dummy living in a region with congestion problems (yes=1)	-0.3274	0.0001	-	-	-0.3709	0.0141	-0.3375	0.0204
dummy days per week congestion delay (≥3 times=1)	-	-	-	-	0.5794	0.0003	0.4798	0.0012
dummy size municipality (≥50,000 inhabitants=1)	-0.2916	0.0004	-0.2030	0.0337	-0.2443	0.0943	-0.4895	0.0022
dummy annual commute and private km in car (>19,000 km =1)	-	-	-	-	0.6555	0.0001	0.2949	0.0391
dummy working hours/week (≥35 hours/week=1)	0.5600	0.0000	0.6112	0.0000	-	-	-	-
dummy travel cost compensation employer (completely compens.=1)	-0.3482	0.0001	-0.5039	0.0000	-	-	-	-
dummy arrival time constraint (yes=1)	-	-	-	-	0.2883	0.0847	-	-
dummy possibility to work at home (always, sometimes =1)	-	-	-	-	0.3210	0.0709	-	-
dummy planning to change house within 2 years	0.7348	0.0000	-	-	0.7373	0.0000	-	-

Change residential location (closer to work)	**Km charge 1,2,3**				**Cordon charge**			
	M1: ordered probit		**M2: removal high house probability change 2 yr**		**M3: ordered probit**		**M4: removal high house probability change 2 yr**	
	Coefficient	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**
dummy planning to change job within 2 years	-	-	-	-	-0.4836	0.0049	-	-
dummy passage number of cordons (1 cordon=0; 2 cordons=1)	-	-	-	-	-	-	0.4004	0.0115
Perceptions and behavioural changes								
dummy house/living satisfaction (satisfied=1)	-0.3444	0.0087	-	-	-0.3757	0.1129	-	-
dummy work satisfaction (satisfied=1)	0.3552	0.0025	-	-	-	-	-	-
dummy perception of being better of due to measure (better off=1)	-0.4230	0.0042	-0.4555	0.0080	-	-	-	-
dummy changing short-term trip changes due to rp measure (yes=1)	0.3399	0.0006	0.2354	0.0563	-	-	-	-
dummy prob. moving job due to rp measure (quite to high prob=1)	0.6467	0.0000	0.4666	0.0007	1.1246	0.0000	0.9271	0.0000
μ_1	0.9711	0.0000	1.1564	0.0000	1.0736	0.0000	1.1686	0.0000
μ_2	1.4699	0.0000	1.7493	0.0000	1.5620	0.0000	2.0010	0.0000
N (number of respondents in estimation)	1152		873		366		345	
Log likelihood (constants)	-1009.3		-626.7		-343.9		-308.4	
Log likelihood (convergence)	-888.8		-566.8		-286.1		-268	
X^2	241.0		119.7		115.6		80.7	

the residential relocation probability due to (road) pricing. The sign of the coefficient is positive, which indicates that respondents who are likely to move house within two years anyway are more likely to be extra influenced in their decision by the introduction of a road pricing scheme. Furthermore, two location-related factors are significant. Respondents *living in regions in The Netherlands suffering from traffic congestion* are less likely to relocate. A possible reason for this may be that the congestion-prone areas are usually located in denser urban areas. The higher number of (alternative) activities that are available within short ranges in these regions makes it easier to mitigate travel-related costs. The fact that respondents living in *larger municipalities* (≥ 50.000 inhabitants) are also less likely to want to relocate supports this explanation. Compared to the variable 'changing house within two years' the size of these two 'location' coefficients is more than twice as small. In addition to the location-related factors mentioned above, respondents who have a higher *income*, *education* and who *own a house* indicated, as was to be expected, that they are less likely to relocate as a result of road pricing measures. Respondents with *children,* on the other hand, have a higher probability of moving. Although this variable is significant, the explanatory strength compared to for example the variable *changing location within two years,* is relatively small.

Within the second category of explanatory variables (i.e. 'perceptions and behavioural changes') some factors are significant as well. The general picture that emerges is that these factors have a somewhat stronger explanatory power than the variables described above. The variable *changing job* has the strongest influence[124]. Respondents who indicated that they were more likely to change jobs as a result of a road pricing measure are also more likely to move house, as was already reported in section 6.3.3. By contrast, respondents who are *satisfied with their current house* are less likely to move. The power of this effect is (more than) twice as small compared to 'job change'.

The factors described above are significant in the case of both the kilometre charge and the cordon charge model(s). Moreover, the sign of the variables is consistent. However, there are also several factors that are only significant in the case either of the kilometre charge or the cordon charge. We need to be careful when comparing these results, because the respondents were selected on the basis of different criteria (see section 6.3.2). Because of the stricter criteria applied in the case of the cordon charge, fewer respondents were selected. This difference may well have some effect on the outcomes. However, on the basis of the fact that many variables (and the sign of them) are significant in both price measure models, it seems to be legitimate to describe the differences in results as well.

Important factors that are only significant in the case of the kilometre charge are (in order of appearance regarding the strength of the factors): number of work hours, travel cost compensation, the perception of being better off due to the pricing measure and the short-term trip changes. *Fulltime workers* (35 hours or more per week) indicate they are more likely to change house, possibly because they are to a lesser extent able to change their travel behaviour in an attempt to mitigate the financial effects of a road pricing measure. One way to mitigate costs in such a situation may be to relocate, in an attempt to make the (total) trip pattern more efficient (and therefore cheaper). Another explanation is that full time workers will face a road pricing charge more often than part-timers will. As a result, full-time workers face higher travel costs,

124 The reason for including this variable was discussed in section 6.3.4.1.

and may therefore be more likely to relocate. Subsequently, as expected, respondents who receive a partial or complete *travel cost compensation* (by their employer) are less likely to move house or look for another job because of a kilometre charge.

The variables 'perception of being better of due to the charge' and 'short-term trip changes due to a pricing measure' were only measured for the kilometre charges. Therefore, their influence cannot be tested for the cordon charge. Respondents who have the *perception of being better off due to the charge* are less likely to move house or change jobs. This factor has to be approached with some degree of caution because of a possible causality problem. The direction of causality is doubtful. The question is whether people relocate because of a certain perception of the pricing measure, or whether their intended relocation influences the way they perceive the measure. To account for this uncertainty, models have been estimated without these pricing related perception/attitude factors as well. This analysis showed that at least with respect to sign and significance of coefficients other explanatory factors are not clearly influenced/altered by removing these perception factors. As a result, the road pricing related perception factors were not removed from the final models. To return to the results we find that respondents who want to make *changes in their current short-term trip behaviour* (for example change frequency, mode, departure time) due to a kilometre charge indicated they are more likely to move house or look for another job. This finding may be somewhat counterintuitive. One would expect people who want to mitigate road pricing cost to do so first of all by trying to change their short-term pattern, which is often easier than relocating. If people cannot satisfactorily mitigate their cost via short-term changes they may consider to change locations. Therefore, the finding of a positive interaction coefficient between short and long-term changes must be approached with caution: although on aggregate there seems to be a positive relationship, a substantial amount of individuals may regard trip changes and relocations due to a pricing measure as substitutes. A possible explanation for the positive coefficient sign may (also) have to do with the fact that respondents may find it hard to visualise the consequences of the price measures and to clearly distinguish between the short-term and long-term personal consequences mentioned in the questionnaire. This may lead to the situation whereby (cost sensitive) respondents within the sample more frequently choose to change behaviour in the short-term as well as in the long-term. Finally, respondents with a higher level of *work satisfaction* were found to be more likely to change their residential location due to a kilometre charge. If the work satisfaction is high people may not be willing to change jobs. If they want to reduce the costs of a road pricing measure, they may opt in favour of moving house.

Factors that are more significant in the case of the cordon charge are: the number of kilometres driven, the frequency of congestion delay, the possibility to work at home and change job within 2 years, and the number of cordon passages. The *number of annual kilometres driven by car* for private and commuting purposes has a positive relationship to the likelihood of people moving house and has proven to have a higher explanatory power than looking at the commute distance alone. Respondents who drive more kilometres per year may expect higher travel cost increases due to a price measure, which may result in a higher intention to mitigate those costs, for example by relocating. In addition, respondents *facing traffic congestion delays* three times or more per week and respondents who have *the possibility to work at home* are more likely to move house or change jobs due to the cordon charge only. People who face traffic congestion relatively often may also benefit from a pricing measure if travel time (or travel time reliability) benefits emerge.

Table 6.5: Influencing variables for job relocation probability under influence of a kilometre of cordon charge (ordered probit estimations)

Search another job (closer to home)	**Km charge 1,2,3**				**Cordon charge**			
	M1: ordered probit		**M2: ordered extreme value (Weibull)**		**M3: ordered probit**		**M4: ordered extreme value (Weibull)**	
	Coefficient	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**
Constant	-0.1967	0.3605	0.2154	0.3107	-0.1454	0.5275	0.1635	0.4640
Personal, work and trip-related characteristics								
dummy age respondent (≥45 years = 1)	-0.2361	0.0184	-0.2282	0.0129	-0.4067	0.0052	-0.4592	0.0009
dummy annual gross household income (<28,500 euro=1)	0.4038	0.0019	0.3654	0.0038	-	-	-	-
dummy annual gross household income (>68,000 euro=1)	-	-	-	-	-0.3081	0.0402	-0.2524	0.0781
dummy education (high school, college, university=1)	-0.3214	0.0015	-0.3531	0.0005	-	-	-	-
dummy working partner (yes=1)	0.4994	0.0000	0.4815	0.0000	0.5049	0.0005	0.5501	0.0001
dummy owned house (bought=1)	-	-	-	-	-0.2519	0.0959	-0.3154	0.0363
dummy car medium weight (yes=1)	0.1853	0.0318	0.1696	0.0358	-	-	-	-
dummy heavy car (yes=1)	-	-	-	-	-	-	-	-
dummy gasoline car (yes=1)	-	-	-	-	-	-	-	-
dummy number of cars in household (more than one=1)	-	-	-	-	-	-	-	-
dummy living in a region with congestion problems (yes=1)	-0.1409	0.1182	-0.1801	0.0369	-	-	-	-
dummy days per week congestion delay (≥3 times=1)	0.1805	0.0587	0.2011	0.0269	0.4312	0.0012	0.4371	0.0007
dummy size municipality (≥50,000 inhabitants=1)	-0.1860	0.0330	-0.1771	0.0325	-	-	-	-
dummy annual commute and private km in car (>19,000 km =1)	0.3356	0.0004	0.2396	0.0079	-	-	-	-
dummy working hours/week (≥35 ours/week=1)	0.2319	0.0369	0.2509	0.0166	-	-	-	-
dummy travel cost compensation employer (completely compens.=1)	-0.3268	0.0007	-0.2618	0.0065	-	-	-	-
dummy arrival time constraint (yes=1)	-0.2587	0.0054	-0.3131	0.0007	-	-	-	-
dummy planning to change job within 2 years	0.7811	0.0000	0.8205	0.0000	0.5485	0.0001	0.6466	0.0000

Search another job (closer to home)	Km charge 1,2,3				Cordon charge			
	M1: ordered probit		M2: ordered extreme value (Weibull)		M3: ordered probit		M4: ordered extreme value (Weibull)	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Perceptions and behavioural changes								
dummy work satisfaction (satisfied=1)	-0.5277	0.0000	-0.4801	0.0000	-0.3639	0.0307	-0.2621	0.1372
dummy perception of being better of due to measure (better off=1)	-0.4418	0.0102	-0.3444	0.0184	-	-	-	-
dummy acceptability of rp measures (quite to high accept.=1)	-0.1961	0.1174	-0.1362	0.2332	-	-	-	-
dummy changing short-term trip changes due to rp measure (yes=1)	0.1986	0.0982	0.2193	0.0638	-	-	-	-
dummy prob. moving house due to rp measure (quite to high prob=1)	1.0419	0.0000	1.2070	0.0000	1.2170	0.0000	1.3583	0.0002
μ_1	0.8671	0.0000	0.8684	0.0000	0.7636	0.0000	0.8006	0.0000
μ_2	1.3580	0.0000	1.3135	0.0000	1.2610	0.0000	1.2732	0.0000
N (number of respondents in estimation)	834		834		366		366	
Log likelihood (constants)	-930.8		-930.8		-443.0		-443.0	
Log likelihood (convergence)	-807.3		-799.6		-394.4		-388.6	
X^2	247.1		262.4		97.2		108.9	

However, because travel time benefits were not formulated to the respondents with respect to the relocation probability question, those respondents that face congestion often may feel even worse off as a result of a road pricing measure than other people: they may expect to pay more and not to benefit from the charge. This may make it more likely for them to move, for example to a region where there are fewer traffic delays. However, although this may be an explanation for the observed higher relocation probability of respondents who face congestion regularly, we did not examine whether it is true that those respondents do not expect any (time) benefits as a result of the charge. Moreover, we cannot provide a clear explanation for the finding that respondents who have the possibility to work at home are more likely to change location(s) as a result of the cordon charge. One has to be a bit careful in trying to explain this relation, particularly because it is only significant in the case of the cordon charge (model M3), and even then not in the 'cordon' model estimated on a sample from which those respondents who are willing to relocate anyway were removed (i.e. model M4). Another significant effect is that respondents who already intend to *change their job within two years* for whatever reason are less willing to change their residential location due to a cordon charge. These respondents probably try to mitigate pricing costs by choosing a job location that is situated more efficiently (with respect to travel costs) in relation to the residential location. As a last factor, model M4 (Table 6.4) seems to (logically) indicate that people passing a higher number of cordons per day have a relatively higher residential relocation probability.

Although some factors proved to be only significant either in the case of the kilometre or cordon charge, no clear explanation can be given for the greater part of the differences. That means that beforehand such factors are not explicitly expected to be only significant for explaining differences in the relocation probability due to the cordon or kilometre charges. An example of this is the variable 'facing traffic congestion delays' (see above), which is only significantly explanatory for the relocation probability due to a cordon charge.

6.3.4.3 – Influencing factors for work relocations

Table 6.5 shows the explanatory factors for job relocation due to transport pricing measures. Again, a difference is made between kilometre (i.e. left part of the table) and cordon charges. In contrast to Table 6.4, estimations based on a reduced dataset (i.e. removal of those having a high job change probability in 2 years for whatever reason) are not presented. Nevertheless, these results were actually derived and are (implicitly) taken into account in the description of the results in this section.

Comparing Tables 6.4 and 6.5, a general picture emerges that many of the factors that appeared to be explanatory in the case of residential relocation are significant in explaining the differences in job relocation as well. However, some factors are more important in the case of residential and others for explaining job relocation. We first discuss the most influential factors. As is the case with residential relocation, respondents who are likely to relocate within two years for whatever reason are also more likely to look for another job. The only difference with Table 6.4 is that the explanatory variable in Table 6.5 is the *probability to change job within two years* (instead of the probability of moving house within two years). In line with the result from the previous section the influence of this location probability variable is strong compared to other explanatory factors.

Somewhat related to this variable is the factor *chance of moving location due to pricing*. People who indicated they were likely to change one type of location (in this case the residence) also are more likely to change the other location.

Another significant variable in both Tables is *travel cost compensation*. A higher compensation leads to relatively lower travel costs, and possibly to a lower relocation probability due to pricing. The difference compared to the previous section is that travel cost compensation in the case of job relocation is significant for the kilometre as well as the cordon charge. Further, people assigned to the lowest *income* class (i.e. gross annual household income < € 28,500) indicated a significantly ($\alpha \leq 0.05$) higher probability of changing job (and home) location. And in the case of job change probability due to a cordon charge (Table 6.5) the highest distinguished income class (> € 68,000) also shows a significant effect; respondents within this category have a lower relocation probability. The income results correspond with the expectation that people with a higher income are less likely to relocate due to a road pricing measure. There are also small differences between the models for job-related and residential relocation. The variable *number of annual kilometres driven by car* is significantly explanatory for job relocation due to the kilometre charges as well as the cordon charges; as far as residential relocation is concerned, it is only significant in the case of the cordon charge. However, the sign of the coefficients is the same in both models. Respondents *driving relatively more kilometres by car* (more than 19,000 km/year) indicate that they are more likely to relocate, possibly because they expect they will face higher travel costs than respondents who drive fewer kilometres (see explanation in section 6.3.4.2).

Corresponding with the previous section, people living in a *region with congestion problems* also have a lower job relocation probability (see section 6.3.4.2 for an explanation). This region-specific variable is only significant for the kilometre charge. In contrast, with respect to residential relocation (Table 6.4) the variable is significant for both pricing measures. The size of the coefficient seems to indicate that this variable has a higher explanatory power with respect to residential relocation. *Education* is an explanatory factor for job relocation as well. People who are more highly educated appear less likely to look for another job. There are often fewer suitable jobs available to them. In addition, they often base their job-related decisions on other factors than transport-related ones. Both these aspects can make it less likely for them to relocate. *Fulltime workers* (35 hours or more per week) indicate they are more likely to look for another job. This is in accordance with the results observed for the residential relocation probability (see section 6.3.4.2). Finally, there seems to be some indication that people *owning a house* have a lower probability of changing their job location (i.e. only in the case of cordon charge).

Although the differences in explanatory factors in general are relatively small, except for accent/influence variations, there are some more striking differences. Age, having a working partner, attitude towards road pricing measures and work satisfaction are the most important influencing factors with regard to job relocation. *Age* is significant in all job relocation models and has a larger influence on job relocation than on residential relocation. Respondents older than 45 are clearly less likely to look for another job. A logical explanation for this is that people who have worked longer (in years) have invested more in their firm-specific career (i.e. enterprise-specific human capital[125]), which makes it harder to leave. Moreover, it may be harder for older people to find another job, because their remaining career is shorter, and as a result companies may be somewhat reluctant to hire them. Another important factor in all job change models is the employment status of the partner. Respondents with a *working partner* turned out to be more likely to look for another job when a pricing measure would be implemented. A possible explanation is that the extra commuting costs become so large that the motivation to mitigate those costs increases. Although the influence in the case of job change is significant, no significant outcomes with regard the residential relocation probability were found. Furthermore, the models show the *acceptability of the road pricing measures*[126] to be a significant factor in the case of job change, and not with the residential relocation probability. A higher acceptability leads to a lower job change probability. As expected, *work satisfaction* is a more influential explanatory variable for job relocation than for residential relocation. By contrast, *having children* is an explanatory factor only in the case of residential relocation. Respondents with children seem to be more likely to move house. A possible explanation is that these families already have high expenditures and decide to relocate in order to mitigate the additional costs due to road pricing.

A clear explanation why age and having a working partner are especially explanatory factors with regard to job relocation (due to a pricing measure) and having children is only explanatory for residential relocation change is hard to give. Possibly, the decision to move house is often made at the household level, whereas the decision to look for another job may usually well be an individual decision. Also, the reason why having a working partner has an effect on people's decision whether or not to move house and not on their possible decision to look for another job may be that people tend to consult with each other with regard to where they work. In two-worker households one partner (in most cases the woman) often works close(r) to home (Rouwendal, 1996). In the case of the introduction of a pricing measure, the financial costs especially become higher for the household member with the longest commuting distance. Because one of the partners often already works (quite) close to home, moving into a house that is closer to where the other partner works makes little sense, since it would mean increasing the commuting distance of the first partner. It may make more sense for the partner with the longest commuting distance to try and find a job closer to home.

In addition to the (important) explanatory factors described above, some variables were found to have a less clear sign for residential and/or job relocation, such as the *weight of the car*, *driving a petrol car*, the factor '*arrival time constraints at the work location*' and *owning more than one car*. However, the occurrence of effects that are less easily explained is also inherent in model estimations themselves. Finally, the influence of *gender* was tested but was found to be not significant in the overall model presented in Tables 6.4 and 6.5.

6.3.4.4 – Conclusion and discussion regarding influencing factors

Many factors explain both the residential and the job relocation probability due to transport pricing. The differences between influencing factors for job or house change probability due to a road pricing measure are in general small. The results give some indication that having children,

125 See van Ham (2001) for a further explanation of enterprise-specific human capital.

126 With respect to this factor, the 'causality problem' discussed earlier may exist as well. However, controlling for this variable did not really change other factors. The model outcomes thus seem to be robust.

owning a house, and (other) especially house-related characteristics are more important in explaining the residential relocation probability. Especially the working status of the partner, the number of annual kilometres driven and the acceptability of the charge seem to have a bigger impact on 'the likelihood of people looking for another job. Some differences in the significance of factors are hard to explain. Looking at differences between explanatory variables with respect to the kilometre and cordon charges, we can conclude that they are relatively small. Occurring variations do not seem to follow a systematic pattern. In addition, sometimes differences occur due to variables specifically linked to a certain type of charge (for example the number of cordon passages). Finally, variations in the significance of explanatory factors, taken into account in the estimation of kilometre as well as cordon related models are often hard to explain.

Somewhat unexpectedly, (road pricing related) price level variations occurring within the questionnaire did not have a significant influence on the relocation probability within the overall model estimations (presented in Tables 6.4 and 6.5). The only significant factor linked to price is the number of cordons passed. With regard to the kilometre charge, the annual number of kilometres driven has proven to be more influential than the pricing-related variables. Removing the 'kilometre factor' causes the price level factor(s) to become significant. The fact that price levels are not an important influencing factor with regard to relocation may also indicate that respondents find it hard to really 'feel' the road pricing costs in a stated preference research. This impression is reinforced by the observation from earlier research that a (very) high charge does not lead to an extraordinarily higher relocation probability (Tillema *et al.*, 2004).

The results reported in this section can also be roughly compared to the existing (limited) literature regarding the influencing factors with regard to relocation (due to pricing). As far as we are aware, Arentze and Timmermans (2005) is currently the only other study containing empirical research into the intention of households to move house or change jobs in response to a road pricing measure (see also section 2.7). Arentze and Timmermans carried out an analysis of independent variables explaining the relocation intention and found only a few significantly influential independent factors, probably due in part to the limited sample size. People with a higher education (college or higher) were found to be less likely to look for another job (i.e. significant at 90 percent level) or move house (not significant). This in line with the relationship between education and relocation probability we discussed in the previous sections. Moreover, Arentze and Timmermans found that being male reduces the probability of changing the home location (significant at 95 percent level). By contrast, no significant influence of gender was observed in the previous sections. With respect to household characteristics and the relocation probability, some additional differences emerge. Although they are not significant, the estimations of Arentze and Timmermans indicate that people with children are less likely to move house. The opposite was found in this section: people with children are more likely to move house. This difference may be caused by a difference in the (average) age of the children. Households with children who go to primary/secondary school may be more constrained/confined to certain locations than people without children or whose children have already left school. However, this is not something we investigated, due to the fact that this information is not provided in Arentze and Timmermans (2005). With respect to the effect of urban density, results are comparable:

people in dense urban areas are less likely to relocate due to pricing. A further more striking result is that Arentze and Timmermans, as was the case in this section, did not find a significant influence of the car commute pricing costs (i.e. distance multiplied by road price) on people's intention to relocate. Thus, it would appear that price levels affect people's decision to relocate to an even lesser extent than the short-term trip behaviour by car (see chapter 5).

Kim *et al.* (2005) also examined which independent factors influence people's decision to move house. Although their study did not focus specifically on at road pricing effects, it does provide insight into the influence of several independent factors, among which (general) travel costs to work, on people's decision to relocate. In correspondence with the results in Tables 6.4 and 6.5, Kim *et al.* (2005) found that higher travel time and costs have a positive influence on people's decision whether or not to relocate. The same positive sign was found with regard to having children. As observed here (sections 6.3.4.2 and 6.3.4.3), Kim *et al.* also found that older people are less likely to relocate. There are some differences as well. Some differences between the results of questionnaire 2 and those found by Kim *et al.* (2005) are related to income levels and whether or not people are living in a city. Kim *et al.* (2005) reported that income has a positive effect on people's decision to relocate. By contrast, estimation results shown in this section indicated that households with a higher income have a relatively lower relocation probability (due to road pricing). This may be due to the fact that Kim *et al.* did not focus on road pricing, but on relocation in general: people with higher incomes may generally speaking be more likely to relocate (see Van Wee, 1994). A final important difference is that Kim *et al.* reported a positive relation between living in a city and the decision to relocate, whereas Tables 6.4, 6.5 and Arentze and Timmermans find an opposite relation.

Overall we can conclude that the results concerning the explanatory factors for people's decision/intention/probability to relocate described in section 6.3.4 are quite comparable with the results observed in the limited number of studies that examined the influence of transport costs on people's decision to relocate. Moreover, it seems that a lot of factors that are explanatory with regard to people relocating specifically because of pricing are explanatory with regard to relocation in general[127]. However, it is worthwhile to note that generally speaking high-income households are more likely to move house, whereas they appear to be less likely to move house as a result of the introduction of a road pricing measure, in particular because they are less cost-sensitive.

6.3.4.5 – Sensitivity results for sample size, distribution and repeated choices

This section describes results of the sensitivity analyses that were carried out. First, the sensitivity of the results to changing the sample size is described (i.e. removing respondents who have a high chance of relocating within two years anyway). Secondly, the focus lies on the sensitivity of the results to changes in the distribution of the unobserved factor in the statistical modelling approach used. The last subsection studies the sensitivity of the results when a correction for 'repeated choices' is applied. The reason why we carried out the various sensitivity analyses was provided in section 6.3.4.1.

127 This follows from the comparison with Kim *et al.* (2005) but also from looking at Van Wee (1994) who carried out a literature review into the explanatory factors with regard to residential and work-related relocation.

Influence of the removal of respondents willing to relocate anyway
The models for the reduced sample were estimated independently of the models for the full sample. This means that the analysis of the explanatory factors was carried out separately for the full size and reduced samples.

The influence of removing respondents who are likely to relocate anyway (within two years) does not lead to an overall change in the explanatory factors. The signs of the significant factors remain the same. However, in general the number of significant variables seems to be somewhat lower when removing those likely to relocate. This may be caused by the lower sample size. Although the general picture remains the same, the effect of two factors seems to increase when leaving out those willing to relocate for whatever reason: gross annual household income and travel cost compensation. As expected, the sign of these variables does not change.

Influence of the type of distribution
Models M2 and M4 in Table 6.5 contain the results of the analysis of the explanatory factors for job relocation by using an ordered extreme value (i.e. Weibull) model. M2 was estimated on data based on kilometre charges and M4 on data based on the cordon charge. For estimation of M2, model M1 (i.e. on the basis of the ordered probit model) was used as starting point. Similarly, M3 was used as a basis for M4. Sensitivity analyses for the distribution used were carried out both for job relocation and for residential relocation. Although these results are not included in any of the tables, they are taken into account in our description of the general situation in this subsection.

The results in Table 6.5 as well as the descriptive results with regard to residential relocation indicate that the differences between using the 'base' ordered probit model or the ordered extreme value model in general are small. The sign of all coefficients remains the same. Some coefficient values become stronger, others become weaker. These effects are hard to explain. Overall, the X^2-value[128] (marginally) increases compared to the ordered probit models, indicating that a better model fit can be achieved by using the extreme value distribution. However, the differences in results are too small to conclude that ordered probit models do not provide reliable results on the basis of the asymmetric distributed sample in this study.

Influence of accounting for repeated choices
Table 6.6 contains the results of the sensitivity analysis of the effect of the repeated choice problem for job relocation under the influence of a kilometre charge. Model M1 (left column) represents the original ordered probit estimation, which is the same as model M1 in Table 6.5. Model M2 provides the estimation outcome on the basis of a random parameter model in which all parameters from model M1 were randomized and in which the repeated choice problem was accounted for[129]. The researcher can decide him or her self what parameters are randomized and which statistical distribution(s) is (are) used for capturing preference heterogeneity. As we described in chapter 3 (section 3.5.2), the decision which statistical distribution to use should formally depend on empirical truth (Hensher and Greene, 2003). Triangular distributions have the advantage of bounding distributions, thereby avoiding problems of very large coefficients. Uniform distributions with a (0, 1) bound are sensible in the case of dummy variables (Hensher

128 The X^2-value increases from 241.0 to 248.3.

129 The repeated choice problem was accounted for by using a standard feature in LIMDEP (see Greene, 2002).

and Greene, 2003). With respect to the statistical package we used, LIMDEP, three types of distributions can be selected in the case of the random parameter model: normal, triangular and uniform distributions. The primary goal of estimating a random parameter model in this situation was to take account of repeated choices made by one respondent. Additionally, the model was used to examine whether heterogeneity in preferences exist, but not to examine which distribution leads to the 'best' results. Initially we used normal distributions to capture heterogeneity effects. Applying triangular distributions rather than normal distributions led to quite comparable results. The outcomes based on triangular distributions are not shown. Following the advice of Hensher and Greene (2003), it may have been better to also test a uniform distribution due to the presence of dummy variables, although the authors do not argue that the normal distribution is unsuitable to use in the case of dummy variables either. Moreover, the observed small differences in results between application of normal and triangular distributions may also give some indication that the sensitivity of results to the selected type of 'randomizing' distribution is not high.

When we compare models M1 and M2, several regularities emerge. The overall picture that emerges is that parameter coefficients have a high(er) level of significance within the random parameter model (M2). Another striking distinction is that coefficients become in an absolute sense stronger when we use the random model[130]. Not only coefficients get more 'extreme'. The utility boundary values (i.e. the cut-off values: *μ's*) that are used to determine to which ordinal response class a respondent belongs (on the basis of his/her utility), also become higher. Thus, when applying the random parameter ordered probit model there seems to be a general increase in the scale of the model. According to Revelt and Train (1998), the fact that parameters become substantially higher implies that the random parameters constitute a large share of the variance in unobserved utility. They use this to explain their finding of rising coefficient values when using random parameters in logit estimations (i.e. mixed logit models). However, in this situation it is hard to determine whether the more extreme coefficient values are due especially to a 'scaling-up' effect or must be attributed to the model explaining a higher share of the variance (Revelt and Train, 1998). Another result is that the significance of the parameters increases when applying a random parameter model. Almost all standard deviations are significant too, indicating that there is a considerable degree of heterogeneity in preferences. Finally, when we use the 'random model', the model fit improves substantially, as can be seen from the log-likelihood value. The model fit can be compared on the basis of the log likelihood values, because in essence model M1 and M2 have the same formulation (i.e. the same variables are taken on board). This is due to the fact that model M1 provided the starting values for model M2.

Although the sign of all parameters remains the same in model M2 compared to M1, the relative influence of the coefficients within the separate models sometimes changes. Looking at models estimated for job and residential relocation (i.e. the latter model is not shown here), travel cost compensation is a factor that becomes more influential in both random parameter models compared to the ordered probit model. Other systematic patterns do not really emerge. In general it can be concluded that accounting for repeated choices made by individual respondents

130 There is only one exception for which the coefficient value in an absolute sense is lower and less significant in the random parameter model: perception of being better off. This may be caused by a large variance in the explanatory importance of the variable 'perception of being better off', making the variable itself less explanatory. Indeed Table 6.6 shows a relatively high and significant standard deviation.

(and preference heterogeneity) does not alter the sign of the significant coefficients with regard either to residential relocation or to job-related relocation. Thus, standard ordered probit results presented in Table 6.4 and 6.5 appear to be rather robust.

Although the random parameter models used in the description above account for repeated choices and randomization of parameters, the random parameters are assumed to be uncorrelated. Random parameter ordered choice models allowing random parameters to correlate freely, thereby accounting for correlations of the unobserved (random) portion of utility were estimated as well[131]. A complicating problem was that the estimation procedure did not allow for free correlation of all random parameters within the model (see for the modelling possibilities Greene, 2002), which is why models with a reduced number of random parameters were estimated, one with and the other without free correlation. Estimations were carried out for both job and residential relocation. Comparing the models with and without freely correlated parameters leads to the following regularities. Models accounting for free correlation produce a slightly higher model fit, although the signs of all the coefficients remain the same (i.e. at least for all important relationships). A less clear result was found for the size of the coefficients. Some become stronger when allowing for free correlation; others become weaker. What is more striking is that the standard deviations of the random parameters are often less significant than when the model without free correlation is used. In this latter model, variance may incorrectly be assumed to be caused by preference heterogeneity, whereas in reality it may be partly instigated by (other)[132] correlation effects. However, the results do not indicate that the models with free correlation lead to very different results. Thus, the results in Tables 6.4 and 6.5 still seem to be reliable.

In general, we can therefore conclude that, within the context of this study, the 'problems' involved in repeated choices, preference heterogeneity or other possibly occurring correlations do not to a large extent influence modelling results. In general, the coefficients that were significant when using the 'standard' ordered probit model remain (or become more) significant when we account for correlation. Additionally, the signs of the coefficients remain the same. As a result, ordered probit models seem to lead to robust results within this research.

6.3.5 - Transferability of the relocation probability results to the Dutch working population

In section 6.3.3, we briefly discussed the transferability issue. In that section we took a qualitative look at the influence of the respondent selection criteria on the observed relocation probabilities. With respect to the average car ownership, no substantial difference was found between the sample and the working population. Another selection criterion[133] was that respondents had to be commuters who drive to work by car at least twice a week and face congestion of 10 minutes or more per trip at least twice a week. In section 6.3.3 we concluded that it is very likely that the average Dutch worker faces congestion problems less frequently compared to the average respondent[134]. However, at that point we were unable to draw any meaningful conclusions with

131 By allowing for free correlation, correlations caused by other aspects than preference heterogeneity or the repeated choices only, are also captured.

132 Heterogeneity in preferences may also be seen as a form of correlation (see Hensher and Greene, 2003).

133 This is a selection criterion of one part of the sample (see section 6.3.2).

134 However, no data was found regarding the average number of times per week an average Dutch commuter is faced with traffic congestion.

Table 6.6: explanatory factors job relocation: ordered probit and random parameter ordered choice results

Search another job (closer to home)	**Km charge 1,2,3 M1: ordered probit**		**Km charge 1,2,3 M2: random parameter model (accounting for repeated choices)**	
	Coeff.	**P-value**	**Coeff.**	**P-value**
Constant	-0.1967	0.3605	0.3867	0.1117
Personal, work and trip-related characteristics				
dummy age respondent (≥45 years =1)	-0.2361	0.0184	-0.8992	0.0000
dummy annual gross household income (<28,500 euro=1)	0.4038	0.0019	1.2998	0.0000
dummy annual gross household income (>68,000 euro=1)	-	-	-	-
dummy education (high school, college, university=1)	-0.3214	0.0015	-1.4896	0.0000
dummy working partner (yes=1)	0.4994	0.0000	1.3498	0.0000
dummy owned house (bought=1)	-	-	-	-
dummy car medium weight (yes=1)	0.1853	0.0318	0.7565	0.0000
dummy heavy car (yes=1)	-	-	-	-
dummy gasoline car (yes=1)	-	-	-	-
dummy number of cars in household (more than one=1)	-	-	-	-
dummy living in a region with congestion problems (yes=1)	-0.1409	0.1182	-0.9752	0.0000
dummy days per week congestion delay (≥3 times=1)	0.1805	0.0587	0.8018	0.0000
dummy size municipality (≥50,000 inhabitants=1)	-0.1860	0.0330	-0.8258	0.0000
dummy annual commute and private km in car (>19,000 km =1)	0.3356	0.0004	1.2830	0.0000
dummy working hours/week (≥35 hours/week=1)	0.2319	0.0369	1.2071	0.0000
dummy travel cost compensation employer (completely compens.=1)	-0.3268	0.0007	-1.9686	0.0000
dummy arrival time constraint (yes=1)	-0.2587	0.0054	-0.7535	0.0000
dummy planning to change job within 2 years	0.7811	0.0000	2.7572	0.0000
Perceptions and behavioural changes				
dummy work satisfaction (satisfied=1)	-0.5277	0.0000	-2.2269	0.0000
dummy perception of being better off due to measure (better off=1)	-0.4418	0.0102	-0.3449	0.0622
dummy acceptability of rp measures (quite to high accept.=1)	-0.1961	0.1174	-0.4717	0.0007
dummy changing short-term trip changes due to rp measure (yes=1)	0.1986	0.0982	0.5281	0.0001
dummy prob. moving house due to rp measure (quite to high prob=1)	1.0419	0.0000	5.9467	0.0000
standard deviations				
Constant			0.0788	0.0828
dummy age respondent (≥45 years =1)			0.8212	0.0000
dummy annual gross household income (<28,500 euro=1)			0.6339	0.0000
dummy education (high school, college, university=1)			0.5778	0.0000
dummy working partner (yes=1)			2.1229	0.0000

Search another job (closer to home)	Km charge 1,2,3 M1: ordered probit		Km charge 1,2,3 M2: random parameter model (accounting for repeated choices)	
	Coeff.	**P-value**	**Coeff.**	**P-value**
dummy car medium weight (yes=1)			0.4444	0.0000
dummy living in a region with congestion problems (yes=1)			0.7032	0.0000
dummy days per week congestion delay (≥3 times=1)			0.9554	0.0000
dummy size municipality (≥50,000 inhabitants=1)			1.0201	0.0000
dummy annual commute and private km in car (>19,000 km =1)			0.5944	0.0000
dummy working hours/week (≥35 hours/week=1)			1.7934	0.0000
dummy travel cost compensation employer (completely compens.=1)			0.0177	0.8273
dummy arrival time constraint (yes=1)			0.2911	0.0000
dummy planning to change job within 2 years			3.6532	0.0000
dummy work satisfaction (satisfied=1)			0.9038	0.0000
dummy perception of being better off due to measure (better off=1)			1.4292	0.0000
dummy acceptability of rp measures (quite to high accept.=1)			1.4315	0.0000
dummy changing short-term trip changes due to rp measure (yes=1)			2.6100	0.0000
dummy prob. moving house due to rp measure (quite to high prob=1)			6.9117	0.0000
μ_1	0.8671	0.0000	2.8521	0.0000
μ_2	1.3580	0.0000	5.1347	0.0000
N (number of choices)	834		834	
N (number of respondents)	278		278	
Halton simulations (number)	-		100	
Log likelihood (convergence)	-807.3		-551.0	
X^2	247.1			

regard to the general relocation probability of the Dutch working population, because the direction of the relationship between 'congestion frequency' and relocation probability was not totally clear: are people who experience traffic delays on a regular basis on average more likely to move house or change jobs or is there no significant difference? The analyses described in section 6.3.4 showed that respondents who face congestion problems by car quite often (three times or more per week) have a higher probability of changing their work-related (or residential[135]) location. Keeping in mind the likely overestimation of commuters facing traffic congestion problems within the sample, the relocation probability for the average Dutch population may be somewhat lower, especially with respect to work-related relocation.

135 In the case of the residential relocation, the 'congestion frequency' variable is only significant for the cordon charge.

On the basis of the ordered probit models reported in section 6.3.4, a more elaborate transferability analysis can be carried out by means of sample enumeration. Within the questionnaire, the respondents were asked to indicate the probability that they would change their residential and/or work location due to a pricing measure. This variable was then used as a dependent variable to study the influence of explanatory socio-economic and demographic factors in section 6.3.4. To study the transferability of the relocation probabilities reported in section 6.3.3, this procedure was in fact reversed. The estimated ordered probit models in section 6.3.4, with the explanatory factors for the relocation probability under pricing conditions, were used to predict the residential and job relocation probability for each respondent in the sample. Subsequently, the computed relocation probabilities for all respondents were averaged, which resulted in an average relocation probability for the entire sample. To gain some insight into the transferability of the relocation probabilities, correction factors were computed for several explanatory factors that occur in the ordered probit models. These correction factors indicate whether the sample under- or overestimates the occurrence of people with certain characteristics compared to the average Dutch working population. By applying the correction factors to the ordered probit forecasts, a prediction of the relocation probability for the Dutch working population can be made. Then, a comparison of the average relocation probabilities computed with and without the application of correction factors provides insight into the extent to which relocation probability results derived from the sample are transferable to the Dutch working population. If, for example, differences between the computed probabilities are small, relocation probabilities reported in section 6.3.3 are also representative for the Dutch working population.

Although the procedure described above is in itself a fruitful way of studying the transferability of the relocation probabilities, there is a practical shortcoming. In an ideal situation correction factors can be computed for all explanatory factors occurring within the models. However, for several explanatory factors, especially for those concerned with the respondents' perceptions, no data is available for the average Dutch working population. For these types of factors no corrections can be computed. Due to this 'shortcoming' transferability results must be handled with some care and must rather be regarded as indicative.

To compute the average residential relocation probability for the total sample, the estimated ordered probit model (most left column) in Table 6.4 was used; to compute the average job relocation, model M1 in Table 6.5 (i.e. job relocation probability model) was used. The 'M1-models' in Tables 6.4 and 6.5 were selected because they can be seen as the base models in section 6.3.4, on the basis of which most sensitivity analyses were conducted. In principle other models could have been used as well. To gain insight into the transferability of the results, correction factors were computed for several explanatory variables that arose from the 'M1-models' in Tables 6.4 and 6.5. These correction factors are shown in the fifth column from the left in Table 6.7. The correction values were computed by dividing the characteristic values for the Dutch (working) population[136] by the results for questionnaire 2 (for a certain characteristic). Again, on the basis of the 'M1-models' in Tables 6.4 and 6.5, the average probabilities for residential and work relocation

136 Values of some of the characteristics in Table 6.7 are derived for the average Dutch population. Other figures are based on the Dutch working population. In an ideal case all the characteristics would have been available for Dutch workers. Because this is not the case, the characteristics with regard to the Dutch population may sometimes be slightly different. However, major differences are not expected.

*Table 6.7: applied correction factors per type of relocation (sample enumeration)****

Variable	**Dummy specification**	**Dutch (working) opulation**	**Questionnaire 2, working population**	**Correction factor**	**Application correction factor**
Age tm 65 yr*	45-65 years =1	41.6 %	28.8 %	1.45	Job
Income household (gross/year)*	<28.500 euro =1	35.1 %	18.9 %	1.86	Residence
Education*	High school, college, university =1	41.6 %	50.8 %	0.82	Resid./Job
Working status partner*	Yes =1	24.3 %	69.2 %	0.35	Job
Region*	Congested region = 1(NH, ZH, U, NB)	59.1 %	62.6 %	0.94	Resid./Job
Car weight*	Medium =1 (1000-1250 kg)	35.4 %	46.2 %	0.77	Job
Size municipality*	≥ 50.000 inhabitants = 1	48.9 %	52.3 %	0.93	Resid./Job
Work hours/week*	≥ 35 hours = 1	63.9 %	72.9 %	0.88	Job
Travel cost ** compensation	Yes = 1	App. 80 %	83.3 %	0.96	Resid./Job
Fuel type car*	Gasoline = 1	74.7 %	66.7 %	1.12	Residence
Child(ren)*	Yes = 1	35.9 %	48.8 %	0.74	Residence

* = CBS (2005), ** = Goudappel Coffeng (1997)
*** Some characteristics are only found for the Dutch population in general, i.e.: income, education, region, car weight, size municipality, fuel type car and having children. Other characteristics are specifically related to the working population: working status partner, work/hours per week and travel cost compensation. Finally, age is computed for the population between 18 and 65 years; not all members of this population are necessarily employed.

were computed, this time by including the correction factors into the model. Thereby, the far right column indicates for which type of relocation (i.e. residential or job relocation) the correction factors were used. As described in section 6.3.4.1 the models shown in Tables 6.4 and 6.5 were estimated on significant explanatory factors. Only variables that were actually included in the model estimation were shown in the tables. Thus, as described in Table 6.7, applying correction factors either to job-related relocation or to residential relocation only depends on whether or not a variable emerges in the relocation probability model. For example, the age correction factor was only used in the job relocation model since age is not significant and is thus not taken into account in the estimation of model M1 with regard to residential relocation.

With respect to the residential relocation, the application of correction factors for income, education, the region where people live, the size of the municipality, the travel cost compensation, the fuel type of the car and finally having children leads to a negligible difference in average residential relocation probability. As far as job-related relocation is concerned, differences between the relocation probability computed on the basis of the model with and without the correction factors are also minor if the correction factor for having a 'working partner' is not included. If a correction for this factor is applied, the relocation probability computed on the basis of the model with correction factors slightly underestimates the probability of the 'standard model'. However, even then the computed average probabilities fall between the category response classes 'an extremely low probability' and 'a low probability'.

In conclusion, especially on the basis of the likely overestimation of 'congestion drivers by car' in the sample, the expectation is that the relocation probability will be somewhat lower when the average Dutch working population is considered. On the other hand, however, no indication was found (on the basis of the procedure followed above) that the residential and work relocation probabilities reported in section 6.3.3 will be much different for the average Dutch working population. Nevertheless, the transferability analysis should be considered indicative because it was not possible to derive correction factors for all the significant explanatory factors within the models.

Whereas this section (6.3) focused particularly on the influence of (road) pricing measures on people's decision to relocate (i.e. the first stage in figure 6.1), the next section examines how important various transport (cost) and location-related variables are in the decision where to settle.

6.4 - The influence of (toll related) travel costs in residential location decisions of households

6.4.1 - Introduction

This section describes the results for the second stage, i.e. the decision where to reside (see figure 6.1). The focus is on the influence of transport cost (more specifically toll cost) compared to travel time and house/location-related characteristics in a household's decision where to live. This is studied on the basis of stated choice data. In addition to studying the importance of several travel and location-related characteristics, the influence of explanatory (socio-economic and demographic) characteristics is studied as well.

The residential location decision is studied in relation to the work location by linking the travel based variables to the work location (i.e. commuting travel time and travel costs). The choice was made to look only at the residential location and to relate travel characteristics solely to the work location (and for example not to other activity locations). The reasons behind this choice are twofold (see also chapter 1 section 1.3). First of all the home-work relation is at the centre of urban geographical research (see Hanson and Pratt, 1988); residential locations might have a large influence on job choices and vice versa. These work and residential locations structure the whole daily activity pattern for many people (including choices where to shop, recreate etcetera). In the second place, work and residence locations are easy to imagine for people and are fixed for longer periods.

This section is structured as follows. Sections 6.4.2 and 6.4.3 respectively describe the data and the type of estimation models used. A description of the data was already partly given in section 3.4.3. Moreover, section 3.5.2 already described the main characteristics of the type of models used in this section. But, for the ease of the reader and the consistency of this chapter, data characteristics (and the study design) are shortly resumed in section 6.4.2 and model and estimation characteristics follow in section 6.4.3. The actual results of the analyses, the importance of trip (i.e. toll cost, fuel cost and travel time) and location related variables in a location decision, appear in section 6.4.4. Because model results presented in this section are estimated on basis of a partially different dataset (i.e. household questionnaire 1B) compared to the dataset used in section 6.3 (household questionnaire 2), section 6.4.5 gives a 'rough' insight into how valid results presented in section 6.4.4 are for the sample of respondents used in section 6.3. This analysis is carried out as it is interesting to compare (in a reliable way) the results for both phases in the relocation process.

6.4.2 - Data characteristics and the study design

A stated choice approach was followed to examine the impact of road pricing on the residential location choice (see chapter 3, section 3.4.3). To be more precise, the relative influence of trip and location-related variables in the actual choice of residential location is studied. Because stated preference studies focus on 'hypothetical' situations, the researcher has control over the variability within the experiment and can test the influence of several 'desired' factors in people's decision-making process. For more information on the pros and cons of stated preference studies versus revealed preference studies, see chapter 3, section 3.4.3.

The stated choice experiment was conducted among 564 commuters who drive to work by car at least twice per week and who face congestion for 10 minutes or more per trip at least twice a week. Car commuters were chosen because they in particular face congestion problems on a regular basis and are thus affected directly by pricing measures aimed at reducing congestion. An initial analysis showed that a random sample would lead to a relatively low share of lower income workers (i.e. annual gross household income of less than 28,500 euro/year). Because we felt it was important to make sure that lower income groups were represented in our sample, these groups were relatively over-sampled.

Every respondent was presented nine hypothetical choice situations, consisting of two alternatives (see Table 3.4 in section 3.4.3). Each alternative was described by six attributes[137] (number of bedrooms, monthly rent or mortgage costs, location, free flow travel time, travel time in congestion and travel costs) at three levels. Using a three by six (i.e. three levels[138], six attributes) 'standard' design of 27 treatments (see Kocur *et al.*, 1982), all the main effects (and three second-order effects) can be estimated independently. The 27 treatments were divided into three blocks of nine treatments. Each respondent was presented one randomly selected block of choice sets. The actual values of the attributes, such as commute distance, were tailored to the specific situation of the respondents. Respondents only had to select the option (of the two presented to them) they preferred.

6.4.3 - Models for estimation

Choice data, such as those available in this case, can be analysed by using discrete choice models. In chapter 3 (i.e. section 3.5.2) we provided an elaborate overview and explanation of discrete choice models, including the actual model formulations. Section 3.5.2 especially elaborated on explaining two types of models that are (currently) used most often in the case of choice data: the multinomial logit model (MNL) and the mixed logit (ML) model.

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137 Fuel cost variation was based only on the type of fuel, the average fuel consumption per type of fuel and the commuting distance. The fuel cost variable was not part of the design.

138 Three levels are used, because this makes it possible to study the non-linearity of variables as well.

In section 6.4.4, both MNL and ML techniques are used to analyse the trade-offs respondents make between transport costs (i.e. toll and fuel costs), travel time and several housing and/or location-related factors. ML models are used to account for preference heterogeneity and to correct for the fact that one respondent was presented nine choice sets, which may violate the IID-property of MNL models. Specific error structures or correlations between alternatives are not studied explicitly. After making this choice, some additional issues have to be considered regarding (i) the choice of parameters to 'randomize', (ii) the form(s) of the density function(s) $f(\beta)$, (iii) and the type (and number) of simulation draws to be used. With respect to the first point, we decided to test (all) the main attributes within the choice experiment on heterogeneity. This decision was made, since in advance there was no indication for which attributes significant heterogeneity effects could be found. Nevertheless, only models with significant random parameters are finally shown in section 6.4.4. Secondly, with regard to the form of the density function, one is in principle free to choose the type of distribution that is applied for every random variable. In most applications normal and lognormal distributions are used (Train, 2003). The lognormal distribution is often used when the coefficient is known to have a certain sign. For example costs are almost always valued negatively. In addition to (log)normal distributions, uniform and triangular distributions are sometimes applied as well. The advantage of triangular distributions is their ability to bound the distributions, thereby avoiding problems of very large coefficients that can occur when estimating coefficients at the tails of the distribution. In section 6.4.4 different distributions are tested. However, only the distributions that lead to the best (i.e. most significant) results, are presented. The third consideration has to do with the type of simulation draws. Because a simulation approach is needed to estimate mixed logit models an important concern is the number of draws needed to obtain stable results. According to Hensher and Greene (2003), the number of draws required to obtain a stable set of parameter estimates varies enormously and depends on the complexity of the model specification in terms of the number of random parameters that have to be estimated. Nowadays Halton draws are often applied, which take intelligent draws from the uniform distribution rather than random ones (see Greene, 2002; Hensher and Greene, 2003). The Halton procedure appears to vastly reduce the number of draws and thus the time needed for estimation (by 90 percent or more) (Greene, 2002). Therefore, within section 6.4.4 Halton draws are used.

6.4.4 - Toll costs and locational preferences of households

This section aims at providing insight into the trade-offs commuters make between transport costs (especially toll costs), travel time and house- or location-related characteristics. First, section 6.4.4.1 looks specifically at the relative importance of the various trip and location attributes in the residential location decision. With respect to transport costs, a distinction is made between fuel and toll costs. For the estimation itself, multinomial logit (MNL) as well as mixed logit (ML) models are used. However, although mixed logit models account for unobserved heterogeneity in preferences, the resulting standard deviation only provides insight into the variance in heterogeneity and not into factors explaining the variance. Therefore, section 6.4.4.2 elaborates on that topic, by including (especially) socio-economic and demographic explanatory variables into the estimation. Again, both a multinomial and a mixed logit approach are applied.

6.4.4.1 – Relative influence of travel cost, time and location/house factors: base model

Table 6.8 shows results of two 'base model' estimations in which only attributes from the stated choice experiment were taken into account; possible influential socio-economic/demographic or other explanatory factors were left out. At the left part of Table 6.8, MNL results are shown; ML results are presented on the right. In the case of the mixed logit model, five variables produced significant random parameter estimates. Triangular distributions led to the best results for travel time[139], travel cost and monthly housing cost variables. For the variable 'big city' a normal distribution was the most satisfactory. Furthermore, because of their efficiency, Halton draws instead of normal random draws were used in estimating the mixed logit model (see also section 6.4.3 for explanation).

Looking at the sign, significance and relative importance of the variables, the results of both models are comparable. Only the size of the coefficients in the mixed logit estimate is larger, which implies that the random parameters constitute a large share of the variance in unobserved utility (Revelt and Train, 1998). The signs of the coefficients in Table 6.8 are as expected. An increase in the number of bedrooms is valued positively, and cost components, such as the monthly housing cost, travelling costs and travel time, are valued negatively. Travelling cost was subdivided into two variables: fuel and toll cost. Toll costs are valued somewhat more negatively than fuel cost, meaning that respondents on average dislike loosing 1 euro to tolls more than 1 euro to fuel costs. However, the differences in coefficient values are small. Finally, the type of location is a qualitative variable consisting of three levels represented by effect codes (see Louvière *et al.*, 2000 for an explanation of effect codes): (big) city (more than 100,000 inhabitants), medium-sized town/city (10,000 to 100,000 inhabitants), rural area or small town (less than 10,000 inhabitants). Table 6.8 shows that respondents in general dislike living in a big city and prefer to live in a medium-sized or small town/rural area. Note that these results are only representative for respondents who drive to work by car at least twice a week and face congestion on a regular basis.

To illustrate the relative effects of the road pricing measure, Table 6.9 indicates the level of toll and fuel costs (and travel time) that, according to the models, respondents are willing to pay for a certain location benefit. In particular the cost equivalent of each attribute y is calculated as β_y/β_{cost}. Quotients on the basis of the MNL as well as on the basis of the ML model are presented; the ML results are printed *italic* within brackets. Looking at the MNL-based quotients, we see that respondents on average want to pay € 0.40 of toll or fuel cost per day extra (or accept an extra travel time of around nine minutes per day) in order to save € 1 a day on housing costs. This suggests that individuals are more sensitive to travel costs than to housing costs[140]. A possible interpretation is that the willingness to pay for housing is larger than the willingness to pay for travel. The total mortgage of the house generally is nominally constant. Yet, housing prices in The Netherlands use to increase over time at a rate (often) higher than the inflation. This may result in people regarding housing mortgage costs as an investment rather than as an expenditure leading to a lower sensitivity compared to travel costs. However, more emotional reasons may play a role in the lower housing cost sensitivity as well, such as feelings of affection to the house (e.g. 'the

139 No explicit distinction was made between free flow and time in congestion, since the differences in coefficient values are small. In line with what one would expect, travel time in congestion is valued slightly more negatively than free flow travel time.

140 These results must be approached with a degree of caution. Firstly, it is assumed that a month consists of 20 working days, which is not the case for everyone. Secondly, the cost parameters will be affected by the ranges in housing and travel costs presented in the choice experiment.

Table 6.8: trade-offs between travel costs, time and location/house related variables (both MNL and ML results)

	MNL			**Mixed Logit**		
Attributes (base model)	**Coefficient**	**T-value**	**P-value**	**Coefficient**	**T-value**	**P-value**
Bedrooms	0.2641	10.844	0.0000	0.3946	14.251	0.0000
monthly cost	-0.0027	-6.403	0.0000	-0.0050	-6.916	0.0000
big city	-0.4929	-14.450	0.0000	-0.9451	-9.862	0.0000
small town	0.2845	9.238	0.0000	0.4206	10.269	0.0000
toll cost	-0.2949	-15.831	0.0000	-0.7254	-16.919	0.0000
fuel cost	-0.2674	-4.667	0.0000	-0.6583	-6.542	0.0000
travel time	-0.0126	-3.245	0.0012	-0.0261	-4.801	0.0000
st. dev. random parameters:						
monthly cost				0.0092	2.434	0.0149
big city				2.9176	4.586	0.0000
toll cost				1.0555	8.887	0.0000
fuel cost				1.1488	2.829	0.0047
travel time				0.0718	3.280	0.0010
Halton simul.				125 (number)		
adjusted ρ^2	0.1487			0.2603		
-2LogLikelihood	-2990.4			-2591.5		

house is my castle'). With regard to the location-related characteristics, not living in a big city is weighted the highest. The respondents are willing to pay € 3.30 of toll costs (and € 3.70 euro fuel costs) per day or travel 78 minutes per day to avoid living in a big city. All these results also to a greater or lesser extent apply to the mixed logit estimates. The most important difference is that the travel cost (and travel time) components seem to become even more important compared to the other factors in the case of ML estimation.

The relative importance of travel time versus travel cost in people's decision where to live is illustrated by the value of time (VOT), which is computed as (see also Gunn, 2001; Wardman, 2001; Hensher, 2001):

$$VOT = \frac{coefficient \;\; travel\ time}{coefficient \;\; travel\ cost} * 60 \qquad \text{[euro/hour]} \qquad [6.1]$$

The average VOT estimated for the entire sample (on the basis of Table 6.8 and MNL) amounts to 2.6 euro/hour on the basis of toll costs (and 2.8 euro/hour for fuel costs). The fact that the VOT on the basis of toll costs is (somewhat) lower than the VOT based on fuel costs appears to be in line with results described by Wardman (1998), who argues that this lower 'toll cost' VOT reflects an aversion from or protest against paying tolls, although he also states that it is difficult to determine whether this higher VOT is an artefact of the SP exercise or a true reflection of actual preferences. Hensher (2001), by contrast, observes a systematically higher VOT computed on the basis of toll costs. He explains this by the fact that within his SP experiment the mean value and the standard deviation for toll were higher than for running costs (such as fuel costs).

Table 6.9: location benefits compensated by trip costs and travel time (constant utility): MNL (and ML between brackets)

		Compensation trip components		
		Toll cost per day (euro) (2 trips)	**Fuel cost per day (euro) (2 trips)**	**Travel time per day (min) (2 trips)**
Location benefit	Save 1 euro on housing cost/day	0.4 (*0.3*)	0.4 (*0.3*)	8.6 (*7.7*)
	1 bedroom extra	1.8 (*1.1*)	2.0 (*1.2*)	41.9 (*30.2*)
	Not living in a big city	3.3 (*2.6*)	3.7 (*2.9*)	78.2 (*72.4*)
	Living in a small town	1.9 (*1.2*)	2.1 (*1.3*)	45.2 (*32.2*)

The size of the values is low compared to other VOT's found in literature (Gunn, 2001; Wardman, 2001; Hensher, 2001)[141]. In most cases, these 'other' VOT estimates were measured against a context of short-term decisions (route choice, mode of transportation choice, etc.), whereas the choice experiment used in this experiment focuses on long-term (i.e. location) choices. Firstly, we looked for possible 'methodological' reasons for the observed low VOT, both in the construction of the choice experiment as well as in the model estimations. The stated choice experiment was tailored to the specific location and commuting-related situation of the respondents (see section 3.4.3). Moreover, the variation in the attribute values (i.e. the level variation) was considerable but not unrealistically large. Therefore, we believe that the data used are 'reliable'. Secondly, we carefully checked the model estimation procedure. Although an orthogonal design was used to construct the experiment, some correlations between attributes within the experiment exist. Travel time and travel costs are partly correlated because a kilometre based charge was used in the experiment. Due to the (level) variation that was applied around the travel time and cost variables we do not expect, however, that correlations have resulted in the observed low values of time. To study possible reasons more thoroughly, travel time and cost dummy variables were created to estimate values of time for different travel time classes. This, however, did not provide additional insights except that the value of time estimates for different travel time intervals proved to be sensitive to the size and the location (i.e. start and end points) of the intervals. In conclusion, we did not find an indication that the low values of time that were found are due to 'mistakes' in the construction of the choice experiment and in the estimation procedure applied. This would suggest that the trade-off between travel time and travel cost is made differently in the context of the residential choice decision than decisions regarding daily travel. In particular, the involvement of locational benefits that are to be gained appears to reduce the relative importance of travel time (as compared to daily travel costs).

Pérez *et al.* (2003) and Kim *et al.* (2005) also observed a lower 'long-term' compared to a 'short-term'[142] based VOT. Kim *et al.* (2005) for example reported that values of in-vehicle time from residential location choice models were between 64 and 88 percent of those estimated on the basis of mode choice models. In Appendix C estimated 'short-term' based values of time on the basis of the data from household questionnaire 1A are presented (see chapter 3, section 3.4.2 for

141 Values reported by Calfee and Winston (1998), with an average of 3.9 euro/hour, come closer to the values observed in this experiment.

142 This short-term VOT was estimated on the basis of a mode choice model.

an overview of the characteristics of this questionnaire). A huge majority[143] of respondents in household questionnaire 1B (see section 3.4.3) on the basis of which the 'long-term' values of time presented above were estimated, originated from questionnaire 1A. This makes it possible to compare short-term and long-term values of time in quite a realistic way. The mean (short-term) value of time for the total sample presented in Appendix C amounts to € 11.3 per hour. This value is more than a factor four higher than the long-term value of time (i.e. € 2.6-2.8 per hour). Thus, the differences between short-term and long-term values here are even more pronounced than the differences reported, for example, by Kim *et al.* (2005). As we mentioned earlier, it seems that when location factors are incorporated, the influence of travel time in the total preference trade-off of households is reduced.

Whereas the results presented in Table 6.9 and the VOT estimates described above focus on mutual trade-offs between different variables within the experiment, elasticities can provide additional insight into the influence of relative changes in (travel) cost and travel time values on the choice of a certain residential location. Elasticities for monthly housing costs, toll and fuel costs, and travel time are presented in Table 6.10. Estimations were calculated using a multinomial as well as a mixed logit approach. Elasticity in both models is similar, although the size of the values is somewhat larger in the mixed logit model. The elasticity for monthly housing costs is the highest. A ten percent increase of absolute monthly housing costs in alternative A leads to a 6 percent increase of the probability of alternative B being chosen. This elasticity does not mean, as shown before, that monthly housing cost is the most influential variable. The substantially larger elasticity compared to the other factors depends to a large extent on the higher absolute housing cost values. For example, a ten percent increase in absolute monthly housing cost of € 560 (i.e. the mean value in the sample) amounts to € 56, whereas a ten percent rise in toll costs of € 5.60 per day (i.e. mean value in the sample) leads to an increase of € 0.60 euro/day. This latter value is by far smaller on a monthly basis than the increase in housing costs. The elasticity of toll costs furthermore is higher than the elasticity of fuel costs, partly caused by the on average higher absolute toll costs within the choice experiment. Finally, a 10 percent increase in travel time in option A leads on average to a two percent higher chance that B is chosen.

The results described in this section partly correspond to the general picture that emerged in from chapter 2 (section 2.6.3.3). Section 2.6.3.3 described the body of literature with regard to the influence of transport-related factors on people's decision where to live. We concluded that households dislike travel time. However, preferences for some housing attributes, such as the size of the town/city or the type of house, are strong enough to make substantially longer commuting times acceptable in most cases. This is also the picture that emerges in Tables 6.8 and 6.9. However, although travel time is not that important, the same cannot be said about travel (toll) costs. This 'accessibility factor' was found to be one of the most influential factors in the selection of a new residence in this section, whereas, for example, O'Farrell and Markham (1975) found no basis for the conclusion that people trade travel costs against location costs in their choice of residence. However, at the same time it is important to keep in mind that the influence of travel costs observed here is not in total contrast to the body of literature described

143 515 of the 564 respondents in household questionnaire 1B originated from household questionnaire 1A. For more information on the selection of respondents and the link between questionnaires 1A and 1B, see chapter 3, sections 3.4.3 and 3.4.3.

in section 2.6.3.3, because many of the (earlier) studies (reported in chapter 2) did not take travel costs into account explicitly. Kim *et al.* (2005) is a rare example of a study into the influence of travel-related aspects, among other things travel costs, on people's decision where to reside. Although road pricing costs are not included, the results indicate that travel cost is an important factor influencing the selection of a new residence compared to travel time and other location-related factors. Only the quality of schools was more important. This importance of travel cost is also found in this section.

In conclusion, the results presented in this section indicate that toll and fuel costs are important components in residential location decisions of households. Firstly, respondents are more sensitive to changes in travel costs than to equally high changes in housing costs. Secondly, the low VOT indicates that respondents attach a relatively low importance to travel time. Overall, this may lead to the conclusion that respondents in general prefer to pay somewhat higher housing costs and accept longer travel times in order to avoid (high) travel costs. Moreover, toll costs are valued more negatively than fuel costs. However, because of the small (valuation) differences between the two cost components, they are combined into a single travel cost component when looking for explanatory (especially socio-economic/demographic) variables in the next section.

6.4.4.2 – Household influencing characteristics for location preference: extended model

The MNL base model in section 6.4.4.1 assumed homogeneous preferences for all socio-demographic segments. The mixed logit model was used to capture heterogeneity effects. However, although the use of random parameters provides us with insight into the heterogeneity in preferences, explanatory factors remain unknown. In this section we explore the influence of explanatory factors (i.e. socio-economic and demographic) in the choice preferences. Again, two models were estimated. Firstly, an MNL model including explanatory characteristics. Secondly, on the basis of the 'extended' MNL model, an ML model which aimed at capturing the remaining preference heterogeneity.

With regard to the mixed logit estimation, we assumed that the variables 'number of bedrooms', 'monthly cost', 'big city and small town' and the 'travel time and cost' follow a certain probability distribution. For each of these variables, triangular and normal distributions were tested. Normal distributions are often used when the direction of an effect (e.g. living in a big city) is not known in advance. The triangular distribution is regularly applied in value-of-time estimations, because it eliminates the long tail of lognormal distributions, while ensuring the behaviourally correct sign of the VOT (see also section 6.4.3). The best fitting model, based on the significance of coefficients, is presented in Table 6.12, in which a triangular distribution was used for the monthly housing cost, travel cost and travel time coefficients and a normal distribution was applied to the

Table 6.10: elasticities for changes in cost and travel time attributes

	MNL		Mixed Logit	
Elasticities alternative A	**Choice A**	**Choice B**	**Choice A**	**Choice B**
monthly cost	-0.601	0.602	-0.628	0.634
toll cost	-0.305	0.306	-0.372	0.376
fuel cost	-0.154	0.154	-0.207	0.209
travel time	-0.234	0.234	-0.279	0.281

'big city' variable[144]. The standard deviations of the random parameters are lower than in Table 6.8, indicating that some unobserved heterogeneity in Table 6.8 has been converted into observed heterogeneity in Table 6.12. This section reports the mixed logit estimations, since this model explains more of the variance than the MNL model. The equivalent MNL model is displayed for comparison. A further explanation of acronyms used in Table 6.12 is reported in Table 6.11.

Table 6.12 suggests that all four distributed parameters are significant. The fit of the ML model is higher than that of the MNL-model (e.g. due to a higher explained share of the variance in the unobserved utility; see also Revelt and Train, 1998). Although the outcomes are generally speaking similar, there are some differences in the exact size of the parameters. Also, some variables that are significant in the MNL model are not significant in the ML model, possibly due to the random parameters capturing certain effects.

Table 6.12 shows that the 'bedrooms' variable has a negative sign. All interaction terms with the variable 'bedrooms', however, are positive (for example bedrooms x child). For the total sample the mean coefficient value for bedrooms is positive, meaning that one extra bedroom is valued positively. Table 6.12 indicates that commuters who are more highly educated value an extra bedroom more highly than respondents with a lower education level. This may be due to a self-selection effect: probably people with a higher education already live in a bigger house and thus attach a higher value to (the number of) bedrooms. Additionally, as expected, commuters with a working partner or with children also have a positive valuation for an extra bedroom: two-income households on average earn more money than single income households, possibly causing a demand for a relatively bigger house[145]; households with children are on average bigger than households without children and therefore need more space. Moreover, respondents who live in a town with 50,000 inhabitants or more value an extra bedroom more positively than respondents who live in smaller municipalities. Houses in big cities may on average be smaller (at least in the dataset used) than in rural regions, possibly causing inhabitants in big cities to place a higher average value on an additional bedroom. Finally, people who live in an apartment value an extra bedroom more highly than people who live in another type of house, probably due to a lack of space in their current house.

As expected, monthly housing costs are valued negatively. People who are more highly educated, however, dislike monthly housing cost relatively less than people with a lower education. The same applies to respondents who live in a house they own, who may consider the monthly payments more as an investment compared to people who rent. This may make them less sensitive to changes in their monthly housing costs compared to people who rent. Respondents with children dislike housing costs more than people without children, probably due to the higher average expenditures households with children already face.

Looking at the location variable, Table 6.12 shows a strongly negative coefficient for living in a big city. This dislike is even higher for respondents with a partner, living in a (semi-) detached house and/or with a gross annual household income of less than € 56,000. The extra dislike of

144 The random parameter for bedrooms was found not to be significant.

145 Nevertheless, income proved not to be significant. Thus 'having a working partner' is a stronger explanatory variable for preference of bedroom 'space'.

Table 6.11: explanation of acronyms used in Table 6.12

Variables	Explanation
bedrooms (bedr)	number of bedrooms
monthly cost (mnth cost)	monthly cost housing
big city	effect code 1 location (big city)
small town	effect code 2 location (small town/rural area)
travel costs	travel cost (fuel and rp) single trip (euro)
travel time	travel time total single trip (min)
college/university	dummy college/university (yes=1)
working partner	dummy working partner (yes=1)
child	dummy children (yes=1)
large municip.	dummy size municipality (≥ 50.000 inhab. =1)
apartment	dummy apartment (yes=1)
owned house	dummy owned house (yes=1)
detached house	dummy (semi) detached house (yes=1)
no fuel cost	dummy fuel cost compensation (yes=1)
work home	dummy possibility work at home (always, sometimes=1)
partner	dummy partner (yes=1)
dep. time constr.	dummy departure time constraint (yes=1)
gasoline car	dummy car on gasoline (yes=1)
region congest.	dummy congestion sensitive regions in Holland (yes=1)
tta5175	dummy actual travel time (including congestion) between 51 and 75 min (yes=1)
tta76m	dummy actual travel time (including congestion) > 75 min (yes=1)
tte030	dummy travel time shown in experiment between 0 and 30 minutes (yes=1)
income class 1	dummy household income 0-28000 euro/year =1
income class 2	dummy household income 28500-56000 euro/year =1
income class 3	dummy household income >56000 euro/year =1

living in a big city for people living in a larger house can be seen as a self-selection effect: larger houses are more often located in smaller towns/cities (at least in this dataset). 'Lower' (with less than € 56,000 a year) income households finally, may prefer to live in smaller cities or rural areas possibly because over there they can afford better housing for the same price.

Furthermore, the aversion to living in a big city is lower among people with children, who live in a municipality with more than 50,000 inhabitants, who own a house, live in an apartment and/or for households that do not have to pay fuel costs. The fact that households with children have a relatively lower aversion to living in a big city to some extent is unexpected. It may have to do with the opportunities (e.g. schools, sports) that are available in a big city. The positive signs of the coefficients for a larger municipality and for living in an apartment can be seen as self-selection effects. The relatively lower aversion among home-owners compared to people who rent to living in a big city may be explained by the satisfaction they derive from living in their current house or environment. Households that buy a house may in most cases only do so if they like the house and the environment. People who rent a house in a city, on the other hand, may sometimes not have a choice (they may not be able to afford a place that is more to their liking). Overall, the average negative valuation of living in a big city can be caused by a selection bias. People who, for example, like to live in a big city may often work in that same city and as such not be part of the sample (i.e. facing at least 10 minutes congestion on a regular basis).

Table 6.12: trade-off estimation results with inclusion of explanatory characteristics (both MNL and ML results)

	MNL (multinomial logit)			ML (mixed logit)		
Attributes	**Coefficient**	**T-value**	**P-value**	**Coefficient**	**T-value**	**P-value**
bedrooms	-0.1268	-2.137	0.0326	-0.1556	-2.498	0.0125
monthly cost	-0.0065	-5.632	0.0000	-0.0093	-6.382	0.0000
big city	-0.9992	-8.311	0.0000	-1.5160	-5.983	0.0000
small town	0.2280	4.241	0.0000	0.2894	4.500	0.0000
travel costs	-0.7359	-12.459	0.0000	-0.9794	-11.908	0.0000
travel time	-0.0338	-4.652	0.0000	-0.0547	-5.424	0.0000
Heterogeneity:						
bedr*college/university	0.1450	2.780	0.0054	0.2030	3.789	0.0002
bedr*working partner	0.1530	2.980	0.0029	0.1807	3.579	0.0003
bedr*child	0.2114	3.845	0.0001	0.2970	5.206	0.0000
bedr*large municip.	0.2253	4.255	0.0000	0.2575	4.600	0.0000
bedr*apartment	0.2981	4.360	0.0000	0.3971	6.149	0.0000
mnth cost*college/ university	0.0020	2.423	0.0154	0.0025	2.166	0.0303
mnth cost*child	-0.0019	-2.271	0.0232	-0.0028	-2.398	0.0165
mnth cost*owned house	0.0043	3.961	0.0001	0.0059	4.343	0.0000
big city*partner	-0.2661	-3.478	0.0005	-0.3509	-2.242	0.0250
big city*child	0.1713	2.524	0.0116	0.2426	1.808	0.0705
big city* large municip.	0.6929	8.917	0.0000	1.0027	6.897	0.0000
big city*owned house	0.2001	2.815	0.0049	0.3788	2.287	0.0222
big city*detached house	-0.3844	-4.543	0.0000	-0.6838	-4.101	0.0000
big city*apartment	0.6339	7.911	0.0000	1.0393	5.610	0.0000
big city*no fuel cost	0.1795	2.795	0.0052	0.1797	1.400	0.1615
big city*income class 1	-0.2089	-2.208	0.0273	-0.3317	-1.765	0.0775
big city*income class 2	-0.1898	-2.706	0.0068	-0.2219	-1.599	0.1099
small town*large municip.	0.1489	2.317	0.0205	0.1763	2.268	0.0233
small town*gasoline car	0.1455	2.423	0.0154	0.2245	3.001	0.0027
small town*income class 1	-0.2281	-3.071	0.0021	-0.2744	-3.168	0.0015
travel costs*region congest.	-0.0653	-1.989	0.0467	-0.0746	-1.454	0.1460
travel costs*apartment	0.1609	4.187	0.0000	0.1767	2.398	0.0165
travel costs*work home	0.0653	1.989	0.0467	0.0980	1.867	0.0619
travel costs*tta5175	0.1278	2.396	0.0166	0.1573	2.399	0.0164
travel costs*tta76m	0.3667	7.534	0.0000	0.4285	6.778	0.0000
travel costs*income class 2	0.1388	3.347	0.0008	0.0935	1.389	0.1650
travel costs*income class 3	0.1620	3.424	0.0006	0.1615	2.266	0.0234
travel time*dep. time constr.	0.0122	2.292	0.0219	0.0129	1.496	0.1347

Attributes	MNL (multinomial logit) Coefficient	T-value	P-value	ML (mixed logit) Coefficient	T-value	P-value
travel time*tta5175	0.0143	1.823	0.0683	0.0223	2.087	0.0369
travel costs*tta76m	0.0215	2.927	0.0034	0.0388	3.702	0.0002
travel time*tte030	-0.0092	-2.466	0.0137	-0.0110	-2.180	0.0293
st. dev. random parameters:						
monthly cost	-			0.0076	2.424	0.0153
big city	-			1.5617	11.094	0.0000
travel costs	-			0.7416	8.801	0.0000
travel time	-			0.0348	2.079	0.0376
Halton simul.	-			150 (nr.)		
adjusted ρ^2	0.2447			0.3096		
-2LogLikelihood	-2638.1			-2406.6		

In contrast to living in a big city, the coefficient for living in a small town (less than 10,000 inhabitants) is positive. The sign becomes even more positive for people currently living in a bigger municipality. Thus, respondents currently living in a larger municipality on the one hand have (possibly due to self-selection) a lower aversion to living in a big city compared to those living in smaller municipalities, but they may also like the idea of living in a smaller town even more. Respondents who drive a car on petrol also value living in a small town more highly. Finally, respondents in the lowest income class seem to place a relatively lower value on living in a small town. In combination with the earlier described effect of respondents with lower incomes dislike living in a big city to a higher extent, this suggests that on average respondents in the lowest income class seem to prefer living in a medium-sized city.

Looking at the trip-related factors (i.e. travel cost and travel time) several interaction effects can be observed. Respondents living in an apartment and people who have the possibility to work at home value travel cost less negatively. The latter category to some extent will be able to avoid travel costs by working at home. In addition, as expected, people with a higher income value travel costs less negatively, leading to a higher VOT for higher income classes. However, respondents who cannot modify their departure time seem to value travel time less negatively. Apparently, while arriving in time will be important to these respondents, the travel time itself is of less importance.

A special case are the respondents with longer actual travel times. They have significantly lower travel time as well as travel cost coefficients. To draw conclusions on the cost sensitivity of these individuals, the VOT based on the corrected time and cost coefficients is calculated. Looking at the VOT, respondents with a longer travel time in reality (longer than 50 minutes) have a lower value of time. Thus, respondents who currently live relatively far from their work want to pay less to save a certain amount of travel time than people who live closer to work. This may be explained by self-selection: people who prefer low travel times already live closer to work.

6.4.5 - Consequence of sample differences for the comparability of results

Within this chapter a clear distinction has been made between two phases in the relocation process: the probability to relocate (jobs or residence) and the importance of several factors in people's actual decision where to live. Results for the first phase (relocation) were described in section 6.3; results for the second phase were presented in this section (6.4). Although the results for the two phases are presented as being additive, different datasets were used for the analyses in both sections. Due to the partial difference in respondent selection criteria for both datasets (i.e. questionnaire 1B and 2), an important consideration may be to what extent the results reported in section 6.4 are also valid for the sample (household questionnaire 2) used in section 6.3. In this section we briefly discuss this topic, without carrying out an elaborate transferability analysis on the basis of sample enumeration, as was done in section 6.3.5[146].

As reported, the results described within section 6.4.4 (on the basis of household questionnaire 1B) are valid for car commuters who regularly face traffic congestion[147] problems. In contrast to the dataset used for the analyses in section 6.3 (i.e. household questionnaire 2), in section 6.4 no respondents were taken into account that were selected based on the criterion of owning a car. Within household questionnaire 2 (section 6.3), two relocation-related questions were asked. These questions were only presented to working respondents in the questionnaire (see section 6.4.2 for a more elaborate overview of data characteristics). However, these workers did not necessarily have to travel to work by car. By contrast, to study the importance of travel cost versus location-related variables in the final location where to reside (i.e. section 6.4), the focus was on car commuters only (i.e. household questionnaire 1B). This made it easier to construct a stated choice experiment in which the travel costs were specifically tailored to the respondents' current commuting trip by car. Moreover, only drivers who face congestion regularly were taken into account because they are most likely to face pricing measures aimed at reducing congestion.

Road pricing measures in the short-term influence travel costs (first order effect) and are particularly aimed at reducing travel times by influencing people's behaviour (i.e. second-order effect). For these reasons studying the transferability of the results for travel cost and travel time may be particularly interesting. The most striking differences in characteristic values between questionnaires 1B and 2 were found with regard to the congestion frequency and the commuting distance. In questionnaire 1B, the median value for the weekly number of morning peaks in which respondents are stuck in traffic is 3.6. In questionnaire 2, people were asked a somewhat different question with regard to the frequency of being stuck in traffic: the weekly number of times they were stuck in traffic. The mean value in questionnaire 2 (only the working sample) is 2.9 times. Because it is quite likely that a substantial amount of people are facing congestion problems both in the morning as well as in the evening, the value of 2.9 may even form an overestimation compared to the value of 3.6 times/week in questionnaire 1B. Hensher (2001) found that the people value travel time in congestion more negatively than free flow travel time, leading to a higher value of time in congestion. From this point of view, the value of time computed on the basis of the sample for household questionnaire 1B (i.e. section 6.4) may be larger than would

146 Sample enumeration is less useful in this case because the dependent variable is relatively vague (i.e. the choice of one of the two options within a choice set) compared to the relocation probability.

147 More precisely: people who experience a travel delay by car to work with a minimum of 10 minutes at least twice a week.

have been found for the average respondent in household questionnaire 2. On the other hand, the average commuting distance in questionnaire 1B is substantially higher. Table 6.12 showed that respondents (in questionnaire 1B) with a higher current commuting travel time[148] (i.e. larger than 50 minutes in one direction) have a lower value of time. Because the average commuting distance in questionnaire 2 is substantially smaller, values of time might have been higher if the sample of questionnaire 2 had been used. Thus, 'transferability results' may be somewhat in contrast: with respect to congestion frequency questionnaire 1B may overestimate the value of time compared to household questionnaire 2; for commuting distance an underestimation may occur. Overall, it is impossible to determine on the basis of this simple analysis which of the two effects weighs stronger. However, there is no clear indication that results will change much due to sample differences since the two effects (partly) mitigate each other.

6.5 - Conclusions and considerations

6.5.1 - Conclusions

In this chapter we explored the longer-term effects of road pricing: people's decision whether or not to move houses or change jobs and their choice of residence. These effects may be of potential importance as they lead to changes in origin-destination relationships, possibly affecting mode choice and congestion levels as well as the housing and labour market. More specifically, on the one hand this chapter focused on gaining more insight into the effect of road pricing on the likelihood of people relocating, and on the other hand on the relative influence of trip and location-related variables in the actual residential (not the job-related) location choice.

For studying the probability of changing the residential and/or work locations due to pricing measures, a sample was used that in fact consisted of two sub-samples. One part of the respondents within the sample were selected because they were car commuters who faced traffic congestion on a regular basis, whereas the remainder consisted of working people who owned a car (at least within their household). On average, 4.0 percent of the respondents indicated that the likelihood of them moving due to kilometre charges (averaged over three different kilometre charges) was quite high, high or extremely high. The probability of them looking for another job was even significantly higher (about 10.7 percent averaged over the three kilometre charges). In addition, cordon charge-based measures seem to lead to a higher average likelihood of people moving than the kilometre charges: on average 6.9 percent of the respondents are reasonably likely to change their residence and 16.3 percent to change their work location. It must be remarked that a majority of respondents (approximately 75 percent) who indicated a high probability of relocating due to the road pricing measures already have a reasonably high chance of relocating within 2 years anyway. Thus particularly respondents who are already likely to change their residential or work location within two years intend to relocate due to road pricing. It seems that pricing in such situations can provide the 'encouragement' needed. With respect to the size of the probabilities/intentions presented, the results seem to be quite in line with the results from one other known study, which focuses explicitly on people's intention to move house and/or look for another job as a result of a road pricing measure on the basis of empirical

148 Although travel time is not the same as travel distance, a higher travel time often goes hand in hand with a longer travel distance.

data (Arentze and Timmermans, 2005). However, a difference is that Arentze and Timmermans found people are more likely to move house than they are to change jobs.

Several variables were found to explain the differences between respondents in the likelihood of them moving house or changing jobs specifically due to a road pricing measure. Important influencing factors, with corresponding signs between brackets indicating their relationship with relocation probability, are: gross annual household income (-), the annual number of kilometres driven (+), the degree of travel cost compensation from employers (-), the education level (-) and the probability of relocating within 2 years for whatever reason (+). Additionally, attitudes towards and short-term trip changes due to road pricing appear to be significant explanatory factors. In general, the observed explanatory factors for relocating due to (road) pricing measures are often similar and of the same sign as can be found in general 'relocation' studies. The most important difference is that factors like income and travel cost compensation seem to play a more important explanatory role in the relocation decision due to road pricing. Moreover, in contrast to 'normal' relocation studies where respondents with a higher income often have a higher (residential) relocation intention (see, for example Van Wee, 1994), such people are less likely to relocate as a result of road pricing.

In general, differences between influencing factors with regard to people's intention to move house or change work due to pricing are small. The same goes for differences in influencing factors between relocation due to a kilometre or a cordon charge. Somewhat unexpectedly, the price level of the pricing measure does not seem to play an essential role. The number of kilometres driven can be seen as a proxy for generalized road pricing costs, especially in the case of a kilometre charge. This kilometre-variable however has a higher explanatory power causing the price variable to become insignificant. In accordance with this result, Arentze and Timmermans (2005) also did not find a significant influence of car commuting costs (including the congestion charge) on relocation probability. Thus, it seems that price level (even) has a somewhat lesser influence on long-term (relocation) behaviour than it has on short-term car trip behaviour (see chapter 5). Nevertheless, this finding must be approached with a degree of caution since price influences were not studied as elaborately in this chapter as they were in chapter 5.

Several sensitivity analyses were carried out on the results, in view of the influence of the sample size/construct, the distribution of the unobserved/stochastic factor in the ordered choice model and with respect to the influence of repeated choices made by the same individual. First of all, when omitting from the analyses respondents who are likely to relocate within two years anyway (not due to road pricing), the same important explanatory variables prevail. Secondly, the results do not change substantially when we use different distributions. Finally, accounting for repeated choices, preference heterogeneity or other correlations does not change the sign of the coefficients. Additionally, the same factors remain significant. We can conclude, therefore, that the model results estimated with the standard ordered probit model are relatively robust.

To study the relative influence of trip and location-related variables in the actual residential location choice we used another sample, consisting only of car commuters who face traffic congestion on a regular basis. Looking at the influence of the various variables on people's decision where to live under road pricing conditions, travel (i.e. toll and fuel) cost appears to be an important factor. First of all, respondents are more sensitive to travel costs than to equally high (monthly) housing costs. Secondly, travel time appears to play a less important role[149], as indicated by a low value of time (VOT). Overall, this may lead to the conclusion that respondents in general prefer to pay somewhat higher housing costs and accept longer travel times so as to avoid (high) travel costs. The reliability of these low values of time appears to be supported by Kim *et al.* (2005) and Pérez *et al.* (2003), who also found lower values of time estimated for the longer (e.g. location choice) compared to the shorter term (e.g. estimated on the basis of mode choice models). Looking more specifically at the travel cost components, i.e. toll and fuel costs, we found that toll costs are valued somewhat more negatively than fuel costs, leading to a lower VOT for toll costs. However, the differences between the coefficients of both travel cost components are small. Finally, travel cost is not the only important factor. Location-related factors, such as the type of location and the number of bedrooms, appear to be important factors in a residential location choice as well.

In addition, separate models (i.e. multinomial and mixed logit) were estimated, that include explanatory, especially socio-economic/demographic characteristics[150]. The introduction of these explanatory variables converts some of the unobserved heterogeneity into systematic (observed) heterogeneity. This results in lower standard deviations of the random parameters compared to the mixed logit model that does not include these explanatory variables. Focusing particularly on travel time and costs, income appears to be an important socio-economic characteristic. Respondents with a higher income on average value travel costs less negatively, leading to a higher VOT. Another important finding is that individuals who spend more time commuting are less sensitive both to travel time and to travel cost. Their value of time (VOT) is lower, which can be interpreted as a self-selection effect: people who place a lower value on travel time are likely to travel longer distances.

6.5.2 - Considerations

Some considerations may be made on the basis of the results in this chapter. Relocation effects may be important to take into consideration in evaluating the effectiveness of transport pricing measures. This effectiveness is often measured in terms of traffic congestion reduction. Although the expected relocation percentage may look small (compared to trip changes), small changes in traffic intensities at certain time periods and locations due to these relocations can already have considerable impacts on the congestion level. Relocations are likely to lead to cheaper (often shorter) commute distances. Shorter distances may lead to lower congestion levels at certain places in time. Moreover, shorter distances may lead to alterations in mode choice (e.g. more often slow traffic) for several trip purposes (for example commuting, shopping etcetera), which additionally may improve traffic conditions by car. In general, results also showed that car commuters are quite sensitive to travel costs. This sensitivity may imply that although many people do not consider relocating due to pricing, they take travel costs into account when choosing a location where to reside. Since eventually many people change locations during their life, the influence of travel costs may result into more efficient travel patterns (for example shorter distances) in the long-run. Thus, in conclusion there seems to be a two-stage effect on congestion.

149 This relatively low importance of travel time is in accordance with the general body of literature on the influence of travel-related aspects (especially travel distance and time) on (re)location decisions (see chapter 2, section 2.6.3.3). Travel costs were often not included in these studies.

150 These factors were included in addition to the 'base attribute variables' from the choice experiment.

First of all, some people will decide to relocate specifically due to a (road) pricing measure, which already may have a large impact on the traffic congestion level. Secondly, on the even longer run a large amount of people will change locations for whatever reason. Because on average toll costs seem to be important, the traffic congestion reduction on a long-run may be even larger (due to shorter travel distances in the case of a kilometre charge).

It is important also to emphasize here that the observed relocation probabilities in this chapter do not imply that every respondent who indicated to have a reasonably high probability of changing will actually relocate when a (road) pricing measure is implemented in reality. Stated preference studies may lead to a certain overestimation of the results. Moreover, the reported residential and job relocation probabilities contain respondents who are 'sure' of relocating due to a pricing measure but also respondents who indicated a *quite* high probability of changing. For this last group the actual relocation chance due to pricing probably is less than 100 percent. On the other hand, some of the households that indicated a (quite) low probability of relocating due to road pricing or households who regard a relocation as not likely but not unlikely either in reality in fact relocate due to road pricing. Thus, whether or not the observed probabilities of households that are likely to relocate represent an over- or underestimation of actual relocation percentages is hard to predict.

The range in which the relocation probability percentages fall are not contrary to what one might expect when taking into account the transaction costs involved in buying a house in The Netherlands. Such costs amount to 12 percent of the value of the house (Van Ommeren and Leuvensteijn, 2003). For an average house (e.g. € 230,000, according to RTLZ, July 2006) this means that transaction costs are in the order of almost € 28,000. This means that an average car driver can drive his or her car for many years (paying pricing costs) before the transaction costs are traded off. From this point of view it seems rather illogical that homeowners want to relocate due to a pricing scheme if they do not already intend to do so. The situation is different for people who rent. They do not have to pay transaction costs when they decide to move house. Analyses into the explanatory factors did show that homeowners are considerably less likely to move house as a result of a road pricing measure.

The implicit assumption within the stated preference questionnaire was that house prices did not change as a result of the introduction of transport pricing. However, as a result of changing demand, it stands to reason that house prices will be affected. Some locations may become more and others less attractive. In addition, possible increases in the costs of living due to transport pricing may lead to a reduction in housing prices in general. Another consideration has to do with the transferability of the results to other countries. In other countries the costs involved in relocating may be different, which may affect the likelihood of people deciding to move house as a result of road pricing measures (see e.g. Van Ommeren and Van Leuvensteijn, 2003).

Finally, a remark concerning the influence of probable travel time changes on people's behaviour. Although the results described in this chapter provide some insight into the probability of households to relocate due to the charge, the influence of gains in travel time (and travel time reliability) due to road pricing measures could not be tested on the basis of the questionnaire data, due to limitations of a budgetary nature. Time benefits can have several spatial consequences. Overall, the probabilities of people relocating may change, as (some) people probably did not take the possible benefits into account when indicating the likelihood of relocating. Had the benefits been formulated explicitly, some people might have indicated that they were less likely to relocate, for example because the benefits (partly) compensate the higher financial costs involved in the road pricing measure. On the other hand, other people might have indicated they were more likely to relocate because the travel time benefits might have given them a greater number of options from which to choose. Moreover, it would have been interesting to gain a greater insight into the potential systematic patterns in the relocation 'direction', especially in the case of a cordon charge: for example, does a cordon charge around a particular city on aggregate result in a higher spatial concentration within the city or outside of the city? However, at the same time we want to emphasize that it is difficult to gain insight into such effects because it really depends on the local situation (e.g. large or small city) and on, for example, the characteristics of a particular cordon charge, such as the charge level, but possibly also on the size of the area within the cordon charge (as was analyzed by Eliasson and Mattsson, 2002).

Whereas chapter 5 and this chapter focused particularly on short and longer-term behavioural changes of households due to pricing measures, the next chapter shifts attention to firms. Chapter 7 aims at studying trip change effects and relocation probabilities of firms due to the introduction of a kilometre charge. In addition, we take a look at changes in the perceived accessibility of firms.

7 - Road pricing, changes in accessibility and in short and long-term behaviour of firms

7.1 - Introduction

Whereas chapters 5 and 6 focused on the behavioural effects of transport pricing policies at the household/individual level, in this chapter we address the impact road pricing measures may have on the perceived accessibility of firms on the one hand, and on the short-term and long-term behaviour of firms on the other. Within this chapter, short-term behavioural changes are operationalized as alterations in the (car) trip pattern of firms and changes in employee compensations, product prices and in the radius within which personnel is recruited[151]. Long-term changes are characterized as relocations due to a transport pricing policy. The research question we address in this chapter is (see also section 1.4 for a complete overview of all research questions):

To what extent does (road) pricing influence the perceived accessibility and short and long-term behaviour of firms?

The outline of this chapter is as follows. Section 7.2 describes the most important characteristics of the dataset used. Section 7.3 analyses changes in the (perceived) accessibility of firms due to a (road) pricing measure. Sections 7.4 and 7.5 focus on the impacts of a (road) pricing measure on the short and long-term behaviour of firms respectively. Since this thesis specifically concentrates on geographical implications of pricing measures, as we described in the problem definition in chapter 1 (section 1.3), the main emphasis in this chapter is on changes in geographical accessibility (section 7.3) and on long-term relocation behaviour (section 7.5). This emphasis is translated into more detailed analyses in sections 7.3 and 7.5 (i.e. geography-related topic) compared to section 7.4 (short-term changes). In section 7.3 and 7.5 ordered probit models are presented that provide insight into explanatory/influencing factors for perceived change in accessibility and the relocation probability respectively. With respect to the short-term behavioural intentions (section 7.4), predominantly descriptive analysis results are presented. Whereas the ordered probit analyses in section 7.5 (and in 7.3) provide insight into 'single' firm characteristics explaining differences in the relocation probability (or in perceived changes in accessibility in section 7.3) of firms due to a road pricing measure, section 7.6 extends the analysis. Section 7.6 studies by means of cluster analysis whether or not (homogeneous) groups/clusters of firms can be distinguished that change their behaviour in certain ways due to pricing. Finally, section 7.7 gives conclusions and methodological limitations.

151 Product/service price changes and company policies regarding employee compensations and the recruitment of personnel may also be regarded as long-term changes. Here we made the (practical) decision only to consider relocations as long-term behavioural changes.

7.2 - Data characteristics

In chapter 3, section 3.4.6, we discussed some of the characteristics regarding the questionnaire, which was held among 485 firms. To be more specific, in section 3.4.6 we explained the way we selected firms (i.e. firms operating in the business service or industrial sector). Moreover, we discussed the general structure and content of the questionnaire. However, whereas the description of the questionnaire in section 3.4.6 remained at quite an 'abstract level', this section describes relevant questions in greater detail. The questionnaire merely consisted of the following parts (see section 3.4.6):

- Questions regarding general characteristics of the firms.
- Some questions about opinions and perceptions in the current situation.
- Questions concerning current firm behaviour.
- The description of the pricing measure.
- Questions regarding changes in the perceived accessibility of firms.
- Questions about short and long-term behavioural changes of firms.

Typical questions belonging to the category of 'general questions' are questions regarding the number of settlements of the firm and the number of employees working at the settlement[152], the type (and distribution) of employees[153], the type of activity of the firm[154], and the geographical scale of operation[155]. Furthermore, questions regarding people's opinions and perceptions were aimed at gaining insight into the current accessibility[156] by car, public transport and slow modes, the extent to which the settlement has to deal with traffic congestion[157], but also to find out more about how attractive firms consider their current settlement location[158] (e.g. building and environment). Additionally, firm representatives were asked to indicate on a scale from 1 to 10 the importance and perceived current score of their firm on 19 factors, which may influence a firm's behaviour. Table 7.1 presents these factors.

Next to general firm characteristics and several questions concerning opinions and 'perception', two questions were asked with regard to the behaviour of the firms. The first question was aimed at gaining insight into the compensations employees currently receive (based on the type of employee): compensation for relocation, kilometre/fuel costs and public transport costs, the provision of company cars and, finally, the extent to which employees were offered the opportunity to work at home and choose their own working hours. Compensations were measured on a categorical scale with three classes: never offered, offered only under certain

152 Here, the number of employees working at the settlement that is object of study are meant and not the total number of employees working at all possible settlements of the same firm.

153 E.g. three categories of employees were distinguished: (i) management or executive personnel, professionals, (ii) supportive, facilitating employees (e.g. administration) and (iii) people on the work floor carrying out the jobs.

154 Especially the distinction between the business service and the industrial sector was made.

155 Four scales were distinguished: municipal, regional, national and/or international.

156 Accessibility per transport mode was measured on a 7-point ordinal scale ranging from (1) very bad to (7) very good.

157 This is measured on a 7-point ordinal scale ranging from (1) very few times to (7) very often.

158 This is measured on a scale from 1-10 (only integers).

Table 7.1: characteristics for which firm representatives had to indicate how important each factor is but also how good they think their settlement scores on each factor (all measured on a scale from 1 to 10).

	Characteristics
1.	Representativity building and location
2.	Functional housing/workplaces for employees
3.	Security building and terrain
4.	Accessibility supply and transport of goods
5.	Accessibility for employees
6.	Accessibility for customers
7.	(Low) costs of building and terrain
8.	(Low) cost of goods transport
9.	(Low) costs of business trips
10.	(Low) costs compensation commuting employees
11.	Nearness of comparable firms
12.	Nearness of raw materials and subcontractors
13.	Nearness of knowledge centres/universities
14.	Flexible laws and legislation
15.	Contacts with official agencies
16.	Expansion possibilities within building and on terrain
17.	Parking facilities
18.	Supply of well-suited personnel in region
19.	(Low) competition other firms

Table 7.2: description of pricing measures within the firm questionnaire

Measure	Characteristics
km charge	4 € cent outside and 12 € cent within peak periods, revenues used for lowering income taxes

conditions, and always offered. The second question focused on the likelihood that a firm (settlement) may relocate within two years for whatever reason. This question was measured on a 7-point ordinal scale ranging from very unlikely to very likely.

After the more general questions and questions about the current situation were answered, a road pricing measure was introduced within the questionnaire. To each respondent, one (i.e. the same) pricing measure was shown (see Table 7.2). The initial set-up of the questionnaire foresaw in a kilometre as well as a cordon charge. For budgetary reasons and to keep the length of the questionnaire within acceptable limits, however, the cordon charge was left out. We opted in favour of including a kilometre charge rather than a cordon charge, because it is more likely that a kilometre charge will be implemented in The Netherlands at some point[159].

Transport-related costs are likely to form only a small part of the total operational costs of most firms (see section 2.6.4.2). Therefore, behavioural adaptations of firms are expected to be quite low. To find small (significant) effects, the decision was made not to differentiate too much within the set-up of the questionnaire, which is one of the reasons why we included only one

159 The kilometre charge instead of the cordon charge was also chosen because partners within the MD-PIT project were more in favour of taking the kilometre charge into account.

kilometre charge. The charge is the same as measure 3E in Table 3.5 of chapter 3. This measure was chosen because it is quite a realistic measure[160] with an average price level. Additionally, the overlap between the measures in the household (section 3.4.4) and the firm questionnaire to a certain extent allows us to compare results as a result of road pricing measures for households and firms.

Subsequently, different questions were posed with respect to the implications of the pricing measure for each individual firm. The questions can be roughly categorized into four subject classes: (i) (perceived) accessibility change due to pricing, (ii) short-term behavioural changes and (iii) changes in the long-term and finally, (iv) acceptability related questions. Perceived changes in accessibility were measured in two ways. First of all, for the three accessibility-related factors in Table 7.1 (i.e. numbers 4-6), the respondents were asked to indicate (on a scale from 1 to 10) how well their settlement scores on these characteristics both before and after the introduction of the kilometre charge. The differences in the scores suggest there are changes in the perceived accessibility. Secondly, later on in the questionnaire accessibility was further defined (see section 7.3.2) after which the respondents were asked to indicate to what extent accessibility would deteriorate or improve due to the pricing measure[161]. Four questions were presented, regarding:

- The perceived change in accessibility, without providing additional information of the consequences of the price measure;
- The perceived change in accessibility, taking in mind that the reliability of travel time improves due to the measure (not further defined);
- The perceived change in accessibility, assuming the average time people spend in heavy traffic is reduced by 25 percent due to the price measure;
- The perceived change in accessibility, assuming the average time people spend in heavy traffic is reduced by 50 percent due to the price measure.

Moreover, respondents were asked to indicate the expected short-term behavioural changes of their settlement as a result of the charge. The short-term behavioural questions can be divided into three groups: (i) changes in the trip pattern, (ii) alterations in the compensations and services for employees and (iii) changes in product prices and in the likelihood that the firm will decide to recruit new personnel in the more immediate vicinity of the branch location. Questions in all three groups had to be answered on a 7-point ordinal response scale. The trip pattern questions need some further clarification. These questions were aimed at finding out to what extent firms want to adapt the frequency of their current business trips by car in general, and more specifically to what extent they want to change the current trips undertaken in the peak and off-peak periods. Next to business trips, the same kind of questions were asked for the current trips made for transportation of goods by car/lorry. Finally, intended changes in the use of ICT as substitute for business and commute trips by car were explored.

With respect to long-term behavioural changes, only one question was asked. Respondents had to indicate (on a 7-point scale) the probability that their settlement would relocate within two

160 Such a time-differentiated kilometre charge corresponds quite well with proposals from a policy advisory commission regarding pricing policies in transport (Nationaal platform anders betalen voor mobiliteit, 2005).

161 This was measured on a 7-point ordinal scale ranging from 'the accessibility becomes much worse' to 'the accessibility becomes much better' as a result of the kilometre charge.

years specifically due to the kilometre charge. Some additional questions were asked as well, most of which had to do with the attitude towards the pricing measure for different types of revenue usage. These questions however, are not analyzed within this chapter. For a greater insight into firms' attitude towards the kilometre charge, see Steg *et al.* (2007).

7.3 - (Perceived) accessibility change due to pricing

7.3.1 - Introduction

Geographical accessibility, explicitly linking traffic network effects to activity locations, can be used as a concept to evaluate the effects of different types of road pricing measures. Traffic can mostly be seen as a derived demand since the actual demand is determined by a desire to engage in various activities at different locations. Therefore, geographical accessibility as a policy indicator seems to have advantages above more specific transport network-related accessibility indicators, which do not take the spatial configuration of activity locations into account (see section 2.4.2). The perceived (changes in) geographical accessibility may influence the decision-making and behaviour of various actors, including firms. Due to changes in accessibility firms may, for example, decide to change their trip pattern or, in the long-term, to relocate. However, little is known about the way firms perceive accessibility and, more particularly, about how road pricing changes their perceived accessibility. This section focuses on the perceived change in accessibility of firms due to the type of price measure described above (see section 7.2): the kilometre charge. Specific attention is paid to examining the influence on the perceived change in accessibility of possible travel time or travel time reliability gains as a result of the charge, as road pricing may lead to such benefits. Section 7.3.2 presents changes in the perceived accessibility on the basis of descriptive analyses. Subsequently, section 7.3.3 focuses on (firm) characteristics that influence the perceived change in accessibility due to the presented kilometre charge. The analytical technique used is ordered probit, because the dependent variable (i.e. perceived change in accessibility) is measured on an ordinal scale. Additionally, random parameter models are used to gain insight into the sensitivity of the derived results (see section 7.3.3.1 for a motivation for using random parameter models and see section 3.5.3 for an explanation of random parameter models).

7.3.2 - Perceived accessibility change

7.3.2.1 – Methodology: two ways of measuring perceived accessibility changes

Two types of techniques were used to gain insight into perceived changes in accessibility of firms as a result of the kilometre charge. The first technique implies that respondents had to rate twice (on a scale from 1 to 10) how well they thought their branch scores on several accessibility-related characteristics: once with the assumption of the kilometre charge being implemented and once without that assumption. No definition of accessibility was provided immediately before the 'accessibility-rating task' had to be carried out. However, earlier in the questionnaire respondents had to indicate their current accessibility by car, public transport and slow modes of transportation (see section 7.2). Before these questions were asked, accessibility was defined almost in the same way as in the definition presented below (i.e. the second technique), except for the fact that the definition presented below is tailored only to the car. It may be assumed that the respondent remembered this definition when rating accessibility characteristics of the settlement on a 10-point scale. Changes in the ratings before and after introduction of the measure provide insight into perceived changes in accessibility due to the pricing measure. In total respondents rated the following three 'accessibility' characteristics: (i) the accessibility of the firm settlement for the supply and transportation of goods, (ii) for employees and (iii) for customers. All factors together give more insight into perceived changes in accessibility of firms than each single one because of the broader scope.

The second approach was different and also focused on the influence of possible travel time and travel time reliability gains on the firms' perceived change in accessibility. In the case of this second approach, the respondents were first shown the researchers' definition of accessibility. The following definition was used:

"With accessibility we mean the 'effort' it takes to reach another location (for example customers, the consumer market) by car from the settlement location as well as the 'effort' it takes to reach the settlement by car (for example for employees, customers or suppliers). The 'effort' can depend on all kinds of aspects, such as travel time, reliability of travel time and travel costs."

After showing the definition, four accessibility-related questions were asked. All these questions in principle were the same but only varied with respect to gains in travel time (reliability). As described earlier, the first question was to what extent respondents expect the accessibility of their firm to change due to the kilometre charge[162]. The second question was the same, the only difference being that the respondents were asked also to bear in mind that the kilometre charge improves the reliability of travel time. Reliability of travel time was not further operationalized or quantified[163]. Subsequently, the third and fourth question assumed that the kilometre charge results in a 25 and 50 percent reduction of congestion-related travel time respectively. As described in section 7.2, respondents could rate the accessibility change on an ordinal scale with 7 categories, ranging from 'the accessibility gets much worse' to 'the accessibility gets much better'.

The most important difference between the two approaches is that the first one provides a better insight into changes in various aspects of the perception of accessibility: perceived changes in accessibility for customers, personnel and transportation of goods are studied separately. On the other hand, the second one may offer us valuable insight into the influence on perceived accessibility of potential time and reliability benefits resulting from the charge.

7.3.2.2 – Results: perceived accessibility changes

The results of the first method are described in Table 7.3. The column titled 'before change' gives the mean value of firm ratings before the implementation of the charge; the second column with results gives the average ratings for the situation with pricing. The right column presents the relative change in the average figures. Standard deviations are presented between brackets. Table 7.3 shows that current accessibility ratings regarding the transportation of goods are lower than business/customer ratings, and that these in turn are lower than the average ratings observed for employee accessibility. However, the amount of deterioration is quite consistent for all three accessibility characteristics. On the basis of the results in Table 7.3 we can at the least conclude

162 Respondents were not made aware explicitly of possible travel time or reliability gains.

163 The reason we did not quantify the gains in travel time reliability was that it was difficult to provide an exact indication within the space available in the questionnaire.

that the perceived accessibility of firms worsens as a result of the implementation of the kilometre charge.

The results with regard to the changes in the perceived accessibility due to the kilometre charge derived via the 'second approach' are presented in Table 7.4. Each of its four columns corresponds to the results of one of the four accessibility-related questions. The rows give the percentage of firms that selected a certain ordinal class (on a scale of 7 classes). Absolute numbers are presented within brackets. Furthermore, sum totals of the categories are included at the bottom of the table. The first column shows that the majority of firms, 78 percent, expects no changes due to the kilometre charge. Around 14 percent of the firms indicated that their accessibility would deteriorate. This is higher than the share of firms that expect an improved accessibility (i.e. 7.6 percent). From the firms that perceive an accessibility change due to pricing most think the accessibility only gets somewhat worse or somewhat better; more extreme categories of change have been selected less often. Thus, the general picture that emerges is that most firms do not expect the current situation to change, at least when the benefits are not defined explicitly. In cases where a change is expected, more firms expect the accessibility to become worse rather than better as a result of the kilometre charge.

Table 7.3: changes in the perceived accessibility of firms due to the kilometre charge (approach 1)

Change in perceived accessibility due to km charge	Before charge	After implementation charge	Relative change accessibility [((after-before)/ before)*100]
Accessibility supply and transport of goods	7.12 (1.72)	6.52 (2.04)	-8.4 %
Accessibility for employees	7.58 (1.14)	6.99 (1.63)	-7.8 %
Accessibility for customers	7.50 (1.28)	6.91 (1.72)	-7.9 %

Table 7.4: changes in the perceived accessibility of firms due to the kilometre charge (approach 2)

Changes in accessibility by car from and to the settlement location due to the km charge	Alternative 1: no additional assumptions	Alternative 2: improvement reliability of travel time	Alternative 3: decrease of travel time in congestion with 25 percent	Alternative 4: decrease of travel time in congestion with 50 percent
The accessibility…				
1: Gets much worse	1.4 % (7)	0.6 % (3)	0.6 % (3)	0.8 % (4)
2: Gets worse	5.2 % (25)	2.3 % (11)	2.1 % (10)	1.9 % (9)
3: Gets somewhat worse	7.6 % (37)	4.5 % (22)	2.3 % (11)	1.9 % (9)
4: Stays the same	78.1 % (379)	68.9 % (334)	55.9 % (271)	52.6 % (255)
5: Gets somewhat better	6.6 % (32)	19.8 % (96)	33.2 % (161)	26.8 % (130)
6: Gets better	1.0 % (5)	3.7 % (18)	5.8 % (28)	13.2 % (64)
7: Gets much better	-	0.2 % (1)	0.2 % (1)	2.9 % (14)
gets worse (sum categories 1, 2, 3)	14.2 %	7.4 %	5.0 %	4.6 %
gets better (sum categories 5, 6,7)	7.6 %	23.7 %	39.2 %	42.9 %

Somewhat by contrast, with regard to the questions whereby the benefits of the charge were formulated explicitly, the perceived accessibility on average seems to improve marginally compared to the current situation. When a travel time reliability improvement (not further quantified) is assumed, 23.7 percent of the firms indicate they expect the perceived accessibility to improve, against 7.4 percent who expect it to deteriorate. Again, when we leave aside the category 'no change', most of the responses indicate that only small changes are expected. Explicitly formulated travel time benefits due to the charge even lead to more pronounced improvements in perceived accessibility. These results are shown in the two columns on the right of Table 7.4. On the basis of the assumption that congestion-related travel time is reduced by 25 percent, 39.2 percent of the respondents indicated that their firm's (perceived) accessibility would improve, compared to 5 percent who expected it to become worse. When a 50 percent was assumed, the share of respondents expecting an improvement increases to approximately 43 percent, with only 4.6 percent expecting things to get worse. Most of the respondents who indicated they expected an improvement, expected things to improve slightly. When comparing the results in the two right columns, at first sight firms seem not very sensitive to the size of the travel time benefit. A 25 percent increase in the reduction of congestion-related travel time only leads to an increase from 39.2 to 42.9 percent among firms who perceive an accessibility increase. Nevertheless, when we look more closely at the distribution of frequencies among the 7 classes, the differences between the results with regard to alternatives 3 and 4 are more pronounced. More respondents (around 10 percent more) selected one of the two highest classes (i.e. gets (much) better) in the case of alternative 4 compared to 3.

On the basis of Tables 7.3 and 7.4 it is hard to determine to what extent changes in the perceived accessibility correspond with regard to the two methods we applied. The only thing that can be concluded is that the perceived accessibility due to the kilometre charge for the majority of firms does not change when benefits are not explicitly formulated within the question. To make the comparison between the two approaches easier, Table 7.5, on the basis of the first approach, shows the percentage of respondents who gave a higher, lower or the same rating for the various accessibility-related characteristics before and after the kilometre charge was presented. When we combine the three characteristics, 5-6 percent assumed an increase in accessibility. Most of the respondents (i.e. 66-68 percent) do not expect the accessibility to change. When we compare the results in Table 7.5 with the results for alternative 1 in Table 7.4 (i.e. no explicit formulation of benefits), the results are quite similar. The percentage of respondents that awaits a higher or the same accessibility is somewhat higher in Table 7.4. Thus, overall the image arises that the second approach leads to a somewhat more optimistic picture of changes in accessibility compared to the first approach. Although the differences are small, the way of measuring changes in accessibility to a certain extent appears to influence the results.

Table 7.5: changes in the rating of accessibility related characteristics due to the kilometre charge

Rating accessibility change	Accessibility supply and transportation of goods	Accessibility for employees	Accessibility for customers
Lower rating with charge	27.6 % (134)	27.4 % (133)	28.5 % (138)
Same rating with charge	67.2 % (326)	67.6 % (328)	65.8 % (319)
Higher rating with charge	5.2 % (25)	4.9 % (24)	5.8 % (28)

What remains unclear is whether or not the respondents implicitly assume that there will be travel time and/or travel time reliability gains when they answer the question regarding their perceived change in accessibility as a result of the charge. We carried out an analysis to find out if the respondents who expected accessibility to improve without having been presented with an explicit formulation of potential travel time benefits also expect congestion levels to fall as a result of the charge. This analysis[164] showed that, although firms that expect congestion levels to fall also tend to expect their accessibility to improve more than other firms do, 70 percent of the firms that expected accessibility to improve without being made aware explicitly of potential travel time benefits did not expect a travel time reduction.

To conclude, a majority of the firms perceive no alteration in their accessibility due to the kilometre charge. Nevertheless, still a part of the firms awaits an (often small) accessibility change. It seems that the perceived accessibility is influenced to a quite large extent by the travel time or travel time reliability benefits caused by a pricing measure. If benefits are not explicitly stated, more firms expect their accessibility to decrease (than to increase) compared to the current situation. But if certain benefits are assumed to occur the perceived accessibility on average improves. Moreover, results indicate that the higher the benefit the larger the accessibility increase is. The accessibility change also seems to be influenced by the type of benefit presented. An increase in the reliability of travel times leads to an on average lower accessibility increase than a reduction in travel time. It remains unclear however, whether this difference can be attributed to the type of benefit (reliability versus travel time gains) or if it is (also) due to the fact that reliability was not explicitly operationalized. We can conclude at the least that travel time benefits on average lead to an increase in perceived accessibility.

7.3.3 - Influencing factors for the perceived accessibility change

7.3.3.1 – Introduction and methodology

To gain insight into factors that influence the perceived change in accessibility due to the kilometre charge, statistical models were estimated on the basis of the four accessibility-related

164 Respondents were asked whether they expected traffic congestion in the Netherlands to fall due to the introduction of the kilometre charge. Answers could be given on a 7-point ordinal scale, ranging from 'extremely unlikely' to 'extremely likely'. 18.1 percent of the respondents expected it to be quite likely, likely or extremely likely that congestion will be reduced. Only 5.9 percent, however, selected either the option 'likely' or 'extremely likely'. A test was conducted on the basis of the first question in approach 2 (i.e. alternative 1 in Table 7.4) to determine whether respondents who expect congestion to be reduced, expect their accessibility to improve as a result of the charge relatively more often. These 5.9 percent of the respondents make up 29.7 percent of the total share of respondents who expect the accessibility to improve (somewhat) (i.e. sum total of the categories 'somewhat better', 'better' and 'much better'). In addition, 39.3 percent of the respondents who expect congestion levels to fall also thinks that their firm's accessibility will improve; 53.6 percent expect accessibility to stay the same, and only 7.1 percent expect a change for the worse. Thus, firms that expect a reduction in congestion problems envisage an accessibility improvement relatively more often. However, around 70 percent of the firms that expect accessibility to improve do not expect a reduction on congestion levels as a result of the charge.

questions of the 'second approach'[165] (see section 7.3.2 for a description of the second approach). The responses to these four questions were combined into one dependent variable. Because the dependent variable was measured on an ordinal scale, ordered choice models were estimated. In total three alternative models were used to gain insight into the influencing factors and the sensitivity of the results, i.e.: (i) an ordered probit model, (ii) a random parameter ordered choice model, (iii) and a random parameter ordered choice model allowing for correlation between the random parameters.

The first of the three models mentioned above, the ordered probit model, can be regarded as one of the 'standard' models, together with to the ordered logit model, for analyzing categorical data. The difference between both the ordered probit and logit model is that the former model assumes that the unobserved factors are distributed 'normally', whereas the latter model uses a logistic distribution. As described in chapter 3, section 3.5.3, the ordered probit model has been used within this thesis as the 'standard' model because literature states that the differences in the results produced by the two methods generally speaking are small. Moreover, ordered probit is the default model in the LIMDEP software (Greene, 2002) we have used to estimate models within chapters 5, 6 and 7. The ordered probit model was used here to explore the significance of possible influencing factors separately, and subsequently to estimate a total model with significant influencing factors. This model is presented as model M1 in Table 7.6.

Since one respondent occurs four times within the dependent variable database (i.e. four questions per respondent) and the questions are related, the four answers of one respondent may be correlated. Therefore, random parameter models were estimated as well (i.e. second type of applied models), using the standard ordered probit model as a starting point. The random parameter ordered choice model, which was explained (including equations) in chapter 3, section 3.5.3, is suitable for estimating models on the basis of panel data. Panel data are data in which observations concerning the respondents are collected at different points in time. In this case the repeated choices made by a respondent can more or less be regarded as choices made at different points in time. It must be noted that, although the random parameter model is suitable for estimating a model with repeated choices, somewhat different coefficient values (and significance levels) are likely to be found when four different models would be estimated separately on each of the four accessibility-related questions.

The random parameter model makes it possible to include preference heterogeneity into the model by randomizing parameters within the model. It is up to the researcher to decide which parameters are randomized and which statistical distribution(s) are used to capture preference heterogeneity. The decision which statistical distribution to use, as described in chapter 3 (section 3.5.2), should formally depend on empirical truth (Hensher and Greene, 2003). Lognormal instead of normal distributions are often used when the coefficient is known to have a certain sign. Costs, for example, are mostly valued negatively. Furthermore, triangular distributions have the advantage of bounding distributions, avoiding very large coefficients. Uniform distributions with a (0, 1) bound are sensible in the case of dummy variables (Hensher and Greene, 2003). With respect to LIMDEP, the statistical package we used, three types of distributions can be

165 This second approach was used because it makes it possible to compare the influence of time benefits, which, as we saw earlier, play an important role in the perception of accessibility change, on other firm characteristics.

chosen in the case of the random parameter model: normal, triangular and uniform distributions. Only normal distributions were applied around all the variables within the model, because the normal distribution is a distribution that is well-known and often used. Moreover, the primary goal of estimating a random parameter model in this situation is to test whether heterogeneity in preferences exists, and not which distribution leads to the 'best' results. Application of the normal distribution already led to satisfactory (i.e. often significant) results. In addition, chapter 6 (section 6.3.4.5) provided some indication that the sensitivity to the type of distribution used in estimating a random parameter ordered choice model may not be very high[166].

The random parameters vary per individual and per time period. Additionally, the random parameter model takes a personal or group-specific effect into account, which is the same for every observation per individual (i.e. the same for each 'time period') but varies randomly among individuals. Model M2 was estimated on the basis of model M1, taking into account that one individual in fact makes four choices and additionally assuming preference heterogeneity for all parameters by randomizing them. Model M2, assumes that the random parameters are uncorrelated. Model M3 in Table 7.6, which belongs to the third type of models mentioned above, shows the estimation results of a model that allowed all random parameters to correlate freely, thereby accounting for correlations of the unobserved (random) portion of utility (see also section 3.5.2). The next section focuses on describing these model results.

7.3.3.2 – Influencing factors and differences between models

Table 7.6 presents the estimation outcomes for all three models described above. First the model was fit in a conventional way using ordered probit analysis (i.e. M1 without random parameters) to provide starting values for the random parameter models in M2 and M3 (see Greene, 2002). Since the three models all have the same formulation (i.e. the same variables are used) the log likelihood values can be compared. These likelihood values show that model M3 results in the best model fit, followed by M2 and M1. This indicates that accounting for preference heterogeneity, correlations and the fact that respondents made several choices improves the model fit. Model M3 is used as a basis for describing the results, because this model scores 'best'.

By far the strongest explanatory factors with regard to the perceived accessibility change due to pricing are the travel time benefits, followed by the gain in the reliability of travel time. As we described in section 7.3.2, if benefits are formulated, the perceived accessibility due to pricing is relatively higher. The most influential of the remaining factors is the frequency with which firms are currently faced with congestion problems. Firms that are faced with congestion on a regular basis indicated that they expect their accessibility to improve more (or deteriorate less) as a result of the charge. This may be because firms who currently face traffic congestion more often also benefit more often from travel time (reliability) benefits than firms who do not experience traffic congestion on a daily basis. The latter group only experiences the higher costs, which worsen their relative accessibility compared to the first group.

The remaining factors are somewhat less influential. Firms employing 50 or more employees expect a relatively higher improvement (or lower decrease) in accessibility than firms with

166 This indication is based on applying both triangular and normal distributions in a random parameter choice model estimation in chapter 6. Differences in results were found to be small.

Table 7.6: explanatory variables for the perceived change in accessibility of firms due to the kilometre charge

Influencing factors perceived change in accessibility due to the kilometre charge	**M1: ordered probit model**		**M2: ordered probit random parameter model**		**M3: ordered probit random parameter model + correlation**	
	Coefficient	**P-value**	**Coefficient**	**P-value**	**Coefficient**	**P-value**
Constant	2.0504	0.0000	3.4324	0.0000	6.4441	0.0000
dummy gain in reliability of travel time (yes = 1)	0.5018	0.0000	0.7966	0.0000	1.9769	0.0000
dummy reduction of travel time in congestion 25 percent (yes = 1)	0.8454	0.0000	1.3296	0.0000	2.8128	0.0000
dummy reduction of travel time in congestion 50 percent (yes = 1)	1.0647	0.0000	1.6765	0.0000	3.5824	0.0000
dummy number of employees (≥ 50 employees = 1)	0.1514	0.0045	0.2658	0.0000	0.5065	0.0000
dummy branch (industry = 1)	-0.1812	0.0012	-0.2362	0.0000	-0.3464	0.0000
dummy geogr. operating scale settlement (municipal level = 1)	-0.2949	0.0059	-0.4095	0.0000	-0.6267	0.0000
dummy current accessibility by car/lorry (quite good/good/very good =1)	-0.1506	0.0616	-0.2655	0.0000	-0.1795	0.0539
dummy confrontation with congestion (quite often to extremely often =1)	0.3718	0.0000	0.5479	0.0000	0.9681	0.0000
dummy region settlement (west of The Netherlands = 1)	0.0893	0.1345	0.1856	0.0000	0.0538	0.4580
dummy building characteristics and accessibility (regr. coeff. ≥ 0.9)	-0.1524	0.0271	-0.3221	0.0000	-0.3650	0.0000
dummy firm costs (regr. coeff. ≥ 0.6)	0.1448	0.0177	0.1847	0.0000	0.3042	0.0000
dummy proximity to business relations (regr. coeff. ≥ 0.9)	-0.1449	0.0516	-0.1654	0.0034	0.0667	0.4697
dummy expansion space and parking (regr. coeff. ≥ 0.9)	-0.1910	0.0060	-0.3227	0.0000	-0.3681	0.0000
standard deviations						
Constant			0.6544	0.0000	1.7222	0.0000
dummy gain in reliability of travel time (yes = 1)			0.2621	0.0000	2.6922	0.0000
dummy reduction of travel time in congestion 25 percent (yes = 1)			0.0272	0.5229	0.4903	0.0000
dummy reduction of travel time in congestion 50 percent (yes = 1)			0.4653	0.0000	0.2242	0.0001
dummy number of employees (≥ 50 employees = 1)			0.0628	0.0240	0.2715	0.0000
dummy branch (industry = 1)			0.1718	0.0000	0.7835	0.0000
dummy geogr. operating scale settlement (municipal level = 1)			0.1448	0.0804	0.7029	0.0000
dummy current accessibility by car/lorry (quite good/good/very good =1)			0.4261	0.0000	0.0816	0.1015
dummy confrontation with congestion (quite often to extremely often =1)			0.9154	0.0000	1.0743	0.0000
dummy region settlement (west of The Netherlands = 1)			0.6571	0.0000	0.1527	0.0057
dummy building characteristics and accessibility (regr. coeff. ≥ 0.9)			1.1906	0.0000	0.2665	0.0012

Influencing factors perceived change in accessibility due to the kilometre charge	M1: ordered probit model		M2: ordered probit random parameter model		M3: ordered probit random parameter model + correlation	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
dummy firm costs (regr. coeff. ≥ 0.6)			0.4777	0.0000	0.4948	0.0000
dummy proximity to business relations (regr. coeff. ≥ 0.9)			0.1542	0.0037	0.1847	0.0213
dummy expansion space and parking (regr. coeff. ≥ 0.9)			0.8599	0.0000	0.4484	0.0000
μ_1	0.6120	0.0000	1.3276	0.0000	2.5353	0.0000
μ_2	0.9892	0.0000	1.9354	0.0000	3.8182	0.0000
μ_3	3.1892	0.0000	5.1876	0.0000	10.6626	0.0000
μ_4	4.2284	0.0000	6.8036	0.0000	14.4686	0.0000
μ_5	5.2384	0.0000	8.3551	0.0000	17.8776	0.0000
N (number of respondents in estimation)	1940		485		485	
Halton simulations (number)			100		100	
Log likelihood (constants)	-2128.8					
Log likelihood (convergence)	-1973.4		-1726.5		-1484.8	
X^2	310.7					

fewer employees. It may be that larger firms are less cost-sensitive, which may reduce the effect of the charge on their perceived accessibility compared to that of smaller firms. On the other hand, larger firms may be better able to cope with cost changes, which may lead to a smaller deterioration (or bigger improvement) in their perceived accessibility.

Two parameters with a negative sign are the type of branch and the geographical operating scale of the settlement. The sample contained mainly firms operating in the business service or industrial sectors[167]. Table 7.6 shows that businesses in the industrial sector indicated a relatively smaller improvement (or bigger reduction) in their accessibility as a result of pricing than firms operating in the business service sector. This may be related to a difference in the types of activities in which firms in these two sectors are engaged. Many employees that work in the industrial sector work in shifts, which makes it harder to offer employees the opportunity to work at home or to allow them to change their working hours in order to avoid or reduce charge costs. This is confirmed by the data: compared to firms operating in the business (service) sector, industrial firms significantly less often (i.e. with a reliability of 95 percent) would allow their employees to work at home or modify their working hours if the kilometre charge were introduced. Instead, industrial firms significantly more often (i.e. 95 percent) intend to provide their employees with a kilometre or fuel cost compensation, which leads to higher firm expenditures. Altogether, this may result in industrial firms perceiving a relatively smaller improvement (or bigger reduction) in accessibility compared to firms operating in the business (service) sector. Furthermore, firms that operate mainly at a municipal level (with respect to sales) indicated they expected a relatively smaller improvement (or bigger reduction) in accessibility. This may be because they (believe they) are not faced with congestion problems on a regular basis: delays are often associated with motorways. As a result, they may often face the costs without experiencing the potential benefits. Subsequently, the current accessibility of the settlement by car/lorry is an influencing factor, which is almost significant with a reliability of 95 percent. Firms that regard their current accessibility by car to be good, pointed out a lower increase in accessibility (or a higher decrease) than firms who currently have a lower accessibility. Firms that are already easy to reach do not need improvements and may think less favourably of measures that, as far as they are concerned, will only end up costing them more money.

As described in section 7.2, one of the tasks for respondents was to rate how well they think their settlement currently scores on a list of 19 settlement characteristics that might influence the firm's well behaving (see Table 7.1). These characteristics may influence the perceived change in accessibility due to pricing. Moreover, the current satisfaction of firms with regard to their location and/or branch may affect the likelihood of a firm relocating as a result of a road pricing measure, as we will test below in section 7.5.3. All 19 characteristics say something about the attractiveness and satisfaction of the firm's settlement and location. The responses to some or several of these 19 factors may be interconnected. Therefore, we first carried out a factor analysis to identify a small(er) number of factors that explain most of the variance observed in the 19 variables. The possible smaller number of factors in turn can be used as independent variables

167 On the basis of a database with information about some firm characteristics, firms from the business service and industrial sectors were selected. It later turned out that not all the firms belonged to either of these two sectors. In all 36.3 percent of the sample firms belong to the business service sector, against 50.3 percent to the industrial sector, while the remaining 13.4 percent belongs to another sector altogether.

to explain the differences in the perceived change in accessibility due to the kilometre charge. The possible advantage is that, because of the lower number of independent variables, the analysis into explanatory factors may become clearer. From the factor analysis 5 factors emerged. The factor analysis results are described in full in Appendix F. In this section we focus on the 5 factors that were subsequently used as independent variables when we analysed the explanatory factors for perceived change in accessibility as a result of road pricing measures: (i) building characteristics and accessibility, (ii) firm costs, (iii) proximity to business relations, (iv) regulation and contacts and (v) expansion space and parking. On the basis of the individual regression coefficients that resulted from the factor analysis, dummy variables were created. The higher (i.e. the more positive) the regression coefficient for a firm is, the higher the firm scores on the important characteristics represented by that factor. However, the regression coefficient does not have a dimension and due to that is harder to interpret. Therefore, the level of influence of dummies with different formulations were tested separately. The following dummy boundaries were created for all five factors: dummies with regression coefficients higher/lower than the mean (i.e. always 0) and median[168] value of each of the five factors and coefficients higher/lower than respectively 0.1, 0.25, 0.5, 0.6, 0.8, 0.9 and 1.0. The basic principle used for testing a dummy was that the classes had to be filled with sufficient respondents (minimum 10-15 percent). Model M1 in Table 7.6 presents the factors that were found to be significantly explanatory for the perceived change in accessibility due to the kilometre charge. Only the best fitting (most significant) dummy specifications were taken into account. Model M1 shows that four of the five factors have a significant influence on the perceived change in accessibility. The only factor that has no significantly explanatory power (and as a consequence is not reported in the Table), is the fourth one: 'regulation and contacts'. Nevertheless, as described before, although model M1 forms the basic model formulation used as a basis for estimating models M2 and M3, the significance and direction of explanatory effects are described on the basis of model M3, which is the best fitting model.

Model 3 shows that three of the five factors have a significantly explanatory influence: building characteristics and accessibility, firm costs and, finally, expansion space and parking. Firms that score relatively higher (i.e. regression coefficient ≥ 0.9) on branch location and accessibility-related aspects (factor 1 and 5) indicate a lower accessibility increase (or higher decrease) due to the charge than other firms (i.e. regression coefficient < 0.9). A possible explanation for this may be that these kind of firms (i.e. regression coefficient ≥ 0.9) are already satisfied with their current location (accessibility) to such an extent that they do not need an extra improvement for example in the form of a congestion relief. Higher costs due to pricing are an extra burden for such firms: they do not benefit from the 'traffic' consequences of the measure. In contrast, respondents who currently consider their firm to score better on several cost related components[169] (i.e. regression coefficient ≥ 0.6), perceive a higher accessibility increase (or lower decrease) as a result of the charge. They regard the different cost factors[170] either to be low or not to be really important. This

168 The mean factors used are: 0.049 for factor 1, 0.038 for factor 2, 0.244 for factor 3, 0.149 for factor 4 and 0.043 for factor 5.

169 See Appendix F for an overview of the various cost components that are represented by factor 2.

170 The firm cost factor contains the following characteristics: (low) costs of building and grounds, (low) cost of transportation of goods, (low) costs of business trips, (low) costs compensation commuting employees.

may result in the situation whereby these firms do not mind paying something extra[171] (by way of a kilometre charge) if this means the traffic situation improves.

Finally, the influence of one other variable on the perceived change in accessibility was measured: the acceptability of the kilometre charge. The variable proved to be significantly explanatory with a reliability of more than 95 percent. Respondents who indicated they considered the kilometre charge acceptable also expected a relatively bigger accessibility improvement (or smaller deterioration) than others. However, the question is whether this is a causal direction: whether firms expect accessibility to improve as a result of the charge because they considered the charge acceptable, or whether they consider the charge acceptable because they expect it to improve accessibility. Because we were unable to determine the causal connection in this respect we did not include acceptability in the final model estimations shown in Table 7.6. In addition to the explanatory variables, model M3 (and M2) also contain the standard deviations and significance of the randomized variables. Only one standard deviation is not significant with a reliability of 95 percent: 'current accessibility by car/lorry'. This variable already emerged as one of the less significant variables in the description of explanatory factors presented above. The fact that most standard deviations are significant indicates that there is a substantial amount of preference heterogeneity within the sample.

Comparing the model outcomes from model M3 with those of M1 and M2 some important similarities and differences can be observed. One example is that the signs of all but one coefficient are the same in all models. However, although the parameter for 'proximity to business relations' has a negative sign in models M1 and M2, it is positive in model M3. In the latter model, however, proximity is not significant. Moreover, in model M1 proximity is only significant at the 90 percent level; in model M2 the dummy has a more significant influencing effect (at the 99 percent level). Firms that rate their current settlement higher (regression coefficient ≥ 0.9) on 'proximity to business relations', expect accessibility to become worse to a greater extent (or improve to a lesser extent) compared to other firms. Another difference has to do with the significance of the factor 'region settlement' in the three models. In model M2, firm settlements that are situated within the western part of The Netherlands have a significant higher accessibility increase (or lower decrease) (at the 99 percent level) compared to firms that are located in the 'rest' of The Netherlands. In model M1 and M3 this 'region variable' is not significant at the 90 percent level.

Some more general differences between the three models can be observed as well. The overall picture that emerges is that all parameter coefficients have a high(er) level of significance within model M2 compared to the other two models. Another striking difference is that coefficients become stronger in an absolute sense [172]: M1 coefficients are less extreme compared to model M2, which on its turn are again lower (absolute) than the coefficients for model M3. Not only the coefficients become more extreme. The utility boundary values (i.e. the cut-off values: μ's) that are used to determine to which ordinal response class a respondent belongs (on the basis of his/her

171 They do not mind either because current costs are low or because they do not care greatly about accessibility and branch costs. In both situations, additional costs may not be a serious problem.

172 The single exception, looking only at significant coefficients with a reliability of at least 85 percent, is that the coefficient for current accessibility by car is lower in an absolute sense in M3 than it is in model M2.

utility), also increase from model M1 to M2 to M3. The average increase in the coefficients for the μ-values is quite in line with the average increase in coefficient values. Thus, when applying the random parameter ordered probit model there seems to emerge a general increase in the scale of the model. According to Revelt and Train (1998) the fact that parameters increase substantially implies that the random parameters constitute a large share of the variance in unobserved utility. They use this to explain the rising coefficient values they found when using random parameters in logit estimations (i.e. mixed logit models). However, in this situation it is hard to determine whether the more extreme coefficient values are due especially to a 'scaling-up' effect or must be attributed to the model explaining a higher share of the variance (Revelt and Train, 1998). It is possible the truth lies somewhere in the middle.

To summarize, possible travel time (reliability) benefits due to the kilometre charge strongly affect the perceived change in accessibility of firms: if time and reliability benefits are presented explicitly, firms expect a relatively higher accessibility increase (or lower decrease). In addition, firms employing 50 or more employees and firms that think their branch scores better (than other firms) on several settlement cost, employee cost and trip cost-related aspects also indicated they expect a relatively speaking bigger improvement (or lower decrease) in accessibility due to the charge. On the other hand, businesses in the industrial sector, firms working mainly on a municipal scale with respect to customers/sales and firms that score relatively better on settlement location and accessibility-related aspects indicated they expected a relatively smaller improvement (or bigger reduction) in accessibility as a result of the kilometre charge.

7.4 - Short-term behavioural changes due to pricing

7.4.1 - Introduction

In this section we take a look at the intended short-term behavioural changes of firms as a result of the kilometre charge. In contrast to section 7.3 (and further on in section 7.5), we only discuss the frequency analysis results; no analyses with regard to the explanatory factors of short-term behavioural changes were carried out, as we already discussed in the introduction of this chapter (section 7.1): because this thesis focuses specifically on the geographical implications of road pricing measures, the main emphasis (in this chapter) is on the geographical changes in accessibility and on the long-term relocation behaviour; this means that we analyse factors that explain the differences with regard to changes in the perceived accessibility (see section 7.3.3.2) and/or variations in the relocation probability (section 7.5.3) as a result of the kilometre charge.

With respect to this section, 7.4.2 describes the impacts of the charge on the current trip pattern of firms. Subsequently, section 7.4.3 presents the changes firms envisage with regard to employee compensations. Finally, section 7.4.4 shows to what extent firms want to modify their product/service prices and change the radius within which they want to recruit personnel due to the kilometre charge.

7.4.2 - Changes in the trip pattern of firms due to pricing

In this section, we divide consequences of the charge with regard to travel behaviour into three categories: (i) changes in the number of business trips by car in general and changes in business trips made during and outside the peak period, (ii) changes in the number of trips for

Table 7.7: intended changes in firms' current trip pattern for business trips

Consequences km charge compared to current situation for number of business trips…	By car (overall)	By car outside peak period	By car within peak period
1: Far fewer	1.2 % (6)	0.2 % (1)	2.5 % (12)
2: Fewer	3.1 % (15)	-	7.7 % (37)
3: Little bit fewer	14.5 % (70)	3.9 % (19)	27.5 % (132)
4: Stays the same	77.6 % (374)	56.0 % (270)	57.8 % (277)
5: Little bit more	1.0 % (5)	22.8 % (110)	2.1 % (10)
6: More	1.5 % (7)	13.2 % (64)	1.5 % (7)
7: Far more	1.0 % (5)	3.7 % (18)	1.0 % (5)
do not know/not relevant	3	3	5
total fewer trips (sum categories 1, 2, 3)	18.8 %	4.1 %	37.7 %
total more trips (sum categories 5, 6, 7)	3.5 %	39.7 %	4.6 %

the transportation of goods by car or lorry in general, and changes in the number of trips made during and outside the peak period and (iii) consequences of the kilometre charge for the extent to which firms use (or allow employees to use) information communication technology (ICT) as a substitute for car trips. Table 7.7 shows the changes firms intend to make in their current business trip pattern. Respondents could indicate the changes on a 7-point ordinal scale ranging from many fewer to many more trips compared to the current situation. The table contains three columns with results, the first of which represents the changes in the number of car trips in general. The second and third columns present the changes in trips during and outside of the peak period. In addition to providing the percentages of respondents who selected each of the 7 categories, the categories are also added up at the bottom of the table. The sum of the percentages of categories 1 to 3 represents the total percentage of respondents who expect their settlement to make fewer trips as a result of the charge; by contrast, the combined categories 5 to 7 contain the total percentage of firms intending to make more trips. Respondents who did not have an idea of the change in business trips by car as a result of the charge, or respondents whose firm does not undertake any business trips by car, could select the option 'do not know/not relevant'.

Although the results in Table 7.7 do not offer an exact quantitative insight into the number of trips that will be changed, results give a first indication of the magnitude of the changes. In total roughly 19 percent of the firms responded they would make fewer business trips by car relative to the current situation. Only 3.5 percent indicated the number of trips would increase, possibly because they expect to benefit from travel time gains. Most firms (77.6 percent) do not intend to change anything. From the 19 percent that intend to make fewer business trips by car, most firms (i.e. 14.5 percent) selected the class 'somewhat fewer'. It appears to be more likely that any changes will affect the period during which trips take place than the overall number of business trips. Around 40 percent of the respondents indicated they intended to travel outside peak hours more often, when the kilometre charge level is lower. Roughly 4 percent decides to make fewer trips outside the peak hours. As an additional check for consistency, we also looked at the opposite behavioural change (see column 3): the percentages regarding more or less trips taking place during the peak period. These percentages (38 percent less, 4.6 percent more) are as expected, and are similar to the results in column 2.

Table 7.8: intended changes in firms' current trip pattern for transportation of goods

Consequences km charge compared to current situation for transportation of goods…	By lorry/car (overall)	By lorry/car outside peak period	By lorry/car within peak period
1: Far fewer	0.7 % (3)	0.4 % (2)	1.3 % (6)
2: Fewer	1.1 % (5)	0.7 % (3)	7.0 % (31)
3: Little bit fewer	4.3 % (19)	1.1 % (5)	18.4 % (82)
4: Stays the same	90.5 % (402)	70.2 % (314)	69.7 % (310)
5: Little bit more	1.1 % (5)	14.8 % (66)	2.0 % (9)
6: More	1.4 % (6)	10.7 % (48)	0.9 % (4)
7: Far more	0.9 % (4)	2.0 % (9)	0.7 % (3)
do not know/not relevant	41	38	40
total fewer trips (sum categories 1, 2, 3)	6.1 %	1.9 %	26.7 %
total more trips (sum categories 5, 6, 7)	3.4 %	27.5 %	3.6 %

Table 7.8 presents the intended changes for the car/lorry trips made for transportation of goods. The set-up of the Table is similar to Table 7.7. The first column shows that firms are less inclined to make changes in the number of trips with regard to the transportation of goods compared to changes concerning business trips. Approximately 6 percent chose to make fewer trips. The percentage of firms that intend to make more trips is about 3.5 percent, which is in line with what we observed in table 7.7. An important difference between the two Tables is that the option 'do not know/not relevant' is chosen far more often in the case of the transportation of goods. This indicates that business trips are more likely to be made by each firm than trips for the transport of goods. Subsequently, when we look at firms' intentions to make alterations in the period in which they carry out their transportation (i.e. column 2 and 3), Table 7.8 shows that around 27.5 percent of the firms intend to make more trips outside the peak period when the time-differentiated kilometre charge is implemented. This percentage is somewhat lower than in Table 7.7, which implies that firms that do make trips for the transportation of goods are somewhat less inclined to make changes here. Again, the results of changes in the trips made during the peak (i.e. check for consistency) are in accordance with the results concerning changes in trips made outside the peak hours: the results are opposite and of the same size. Finally, most firms that intend to make any changes indicate they will only do so to a small extent.

Table 7.9 shows the intended changes of firms in the use of ICT. The first column describes to what extent firms expect to make more or less use of ICT as a way of reducing the number of commuting trips made by their employees. An example of this is teleworking. 35 percent of the firms intend to make more use of ICT if the kilometre charge is introduced. Most of them (23.4 percent) select the option 'somewhat more'. Roughly 2 percent of the firms intends to use ICT less often than they do in the current situation. No clear explanation can be given for this finding. It is possible that those firms (2 percent) expect travel time gains, which would make it more interesting to ask teleworkers to come to the office more often. On the other hand, it is also possible that some of these firms are simply opposed in principle to road pricing measures and decide to give a strategic answer. The results with regard to the use of ICT as a substitute for current company car trips (i.e. second result column) correspond with the results for commuting. 35 percent of the respondents indicated they would make more use of ICT as a substitute for current business trips by car. Moreover, the distribution of the answers over the seven classes in the case of business trips is comparable to the results observed for commuting trips by car.

With regard to the questions concerning trip changes, during the fieldwork (i.e. during the data collection phase) we did not check the answers for consistency. In principle this means that respondents could, for example, choose to make fewer business trips overall, more business trips during peak hours and more business trips outside peak hours. This kind of combination would be unrealistic. To gain some insight into inconsistencies, correlations between the various types of trip changes were computed (see Table 7.10). Two types of correlation checks were carried out: (i) correlations between business trip changes overall, during and outside the peak and (ii) correlations between the overall changes with regard to the transportation of goods and changes during and outside the peak period. These two checks are considered the most important in terms of gaining some insight into the reliability of the results; other tests, such as examination of the sign and strength of correlations between business and trip changes for transportation of goods were not undertaken because ex ante no good indication of the to be expected relations can be given. For example, a firm that wants to make substantially fewer business trips by car as

Table 7.9: intended change in the use of ICT possibilities as substitute for commute and business trips

Consequences km charge for use ICT as substitute for current trips compared to use in current situation	ICT as substitute for commute trips (e.g. tele-working)	ICT as substitute for business trips (e.g. email, video conferencing)
1: Far fewer	0.7 % (3)	0.6 % (3)
2: Fewer	-	-
3: Little bit fewer	1.5 % (7)	1.5 % (7)
4: Stays the same	62.9 % (288)	62.8 % (290)
5: Little bit more	23.4 % (107)	24.5 % (113)
6: More	10.3 % (47)	9.1 % (42)
7: Far more	1.3 % (6)	1.5 % (7)
do not know/not relevant	27	23
total fewer trips (sum categories 1, 2, 3)	2.2 %	2.1 %
total more trips (sum categories 5, 6, 7)	35.0 %	35.1 %

Table 7.10: Spearman correlations between intended short-term trip pattern changes of firms due to the km charge (correlations between brackets are not significant at the 95 percent level)

Correlations between trip changes	B	BOP	BIP	TG	TOP	TIP	ICTC	ICTB
Business	X	(-0.035)	0.316	0.191	-0.163	0.104	(-0.003)	-0.093
Business outside peak		X	-0.433	(0.066)	0.438	-0.194	0.277	0.263
Business inside peak			X	(0.098)	-0.260	0.402	-0.160	-0.183
Transport of goods				X	0.330	0.525	0.178	0.153
Transport outside peak					X	(-0.036)	0.264	0.293
Transport inside peak						X	(0.050)	(0.054)
ICT commute trips							X	0.725
ICT business trips								X

a result of pricing may theoretically either choose to make (far) more or fewer car/lorry trips for transportation of goods as a result of road pricing measures.

Table 7.10 shows that the correlation between changes in the overall number of business trips and changes in the number of trips outside peak hours is not significant. On the other hand, there is a positive correlation between changes in the overall number of business trips and changes in the number of trips made during peak hours (+0.316). Because one correlation is not significant and the other one is not very large, it does not appear that the respondents see the changes in the overall number of business trips and changes with regard to the timing of the trips as complete substitutes. This may well imply that firms may change the number of business trips in general and additionally make some changes in the time period during which trips are made as well. Moreover, the positive correlation between changes in business trips overall and changes in car trips made within the peak period seems to be logical: e.g. cost-sensitive firms that intend to lower the frequency of business trips by car are also more likely to divert some trips to the lower cost period outside the peak. Further, in addition to checking the correlations between the number of business trip changes in general and changes per period, Table 7.10 also presents the correlation between changes in the number of trips during and outside the peak period. This correlation is negative (-0.433), meaning that respondents, who intend to make more trips outside peak hours due to the charge, choose relatively more often to make fewer trips inside the peak. This is in accordance with the expectation.

Looking at changes in trips for the transportation of goods, the correlation table shows somewhat different results. Correlations between trip changes overall and per time period are both positive. The correlation between the frequency change overall and the change in the number of trips made in the off-peak period is +0.330; for the correlation with trips during the peak period a value of +0.525 was found. Moreover, no significant correlation was observed between trips outside and inside the peak. In the case of the transportation purpose, trip changes in general and changes in specific time periods seem to be somewhat more complementary than was observed for business trips: firms that decide to make fewer trips in general also seem to decide more often to make fewer trips in both the peak and off-peak period. Nevertheless, the correlation results must be approached with some caution, in particular because Table 7.8 indicates that, in the case of the transportation of goods, firms on aggregate intend to make fewer trips during peak hours and more trips outside peak hours. This result alone could also have led to the conclusion that trips outside the peak are often regarded as substitutes for trips during peak hours. Table 7.10 reveals, however, that there is no significant correlation between changes in transportation trips made outside and inside the peak period.

Overall, it can be concluded that a substantial share of firms considers making changes in their current trip pattern by car (or lorry) as a result of the kilometre charge presented to them. It appears more likely that firms will decide to make more trips during off-peak hours than to reduce the overall number of trips with regard to the transportation of goods. In addition, the changes more often affect business-related trips than the transportation of goods. Probably transporting goods is more vital to the existence of these firms, which makes trip changes less interesting. Lower changes in transport trips might however also be due to fewer alternatives (e.g. other transport modes) that can be chosen for transportation compared to business trips. Whereas, the intended changes in the trip pattern are substantial, most firms, who choose to

Table 7.11: intended changes in the employee compensations/services of firms due to the km charge.

Changes in employee compensations firms due to km charge	Compensation km or fuel costs	Compensation costs PT	Business car	Flexibility in choosing working times	Work at home	Compensation for residential relocation
1: Far less often	2.9 % (14)	2.5 % (12)	3.7 % (18)	3.5 % (17)	2.7 % (13)	6.2 % (30)
2: Less often	6.4 % (31)	3.1 % (15)	7.0 % (34)	1.0 % (5)	0.4 % (2)	1.4 % (7)
3: Little bit less often	9.5 % (46)	3.3 % (16)	9.1 % (44)	2.1 % (10)	0.8 % (4)	2.9 % (14)
4: Stays the same	69.7 % (338)	72.4 % (351)	75.1 % (364)	64.1 % (311)	65.4 % (317)	72.8% (353)
5: Little bit more often	8.2 % (40)	10.5 % (51)	3.7 % (18)	17.5 % (85)	20.2 % (98)	9.7 % (47)
6: More often	2.9 % (14)	6.6 % (32)	0.8 % (4)	9.7 % (47)	7.4 % (36)	4.9 % (24)
7: Far more often	0.4 % (2)	1.6 % (8)	0.6 % (3)	2.1 % (10)	3.1 % (15)	2.1 % (10)
totals:						
less often (cat. 1, 2, 3)	18.8 %	8.9 %	19.8 %	6.6 %	3.9 %	10.5 %
more often (cat. 5, 6, 7)	11.5 %	18.7 %	5.1 %	29.3 %	30.7 %	16.7 %

adapt current trips, want to do that only to a limited extent. Finally, in addition to more 'regular' changes in trip patterns, such as the timing of the trips, ICT also seems to be a promising alternative with regard to business-related or commuting trips.

7.4.3 - Changes in the employee compensations due to pricing

With respect to changes in employee compensations due to the kilometre charge, results are quite dispersed. Around 35 percent of the firms answered that it was likely[173] that they would compensate employees (partly) for the (extra) costs of the kilometre charge. On the other hand, a same share of the firms said that (extra) compensation would be unlikely[174]. Additionally, Table 7.11 offers some insight into the extent to which several types of compensations are affected by road pricing measures. The table shows that approximately 19 percent of the firms intend to offer 'a compensation of the kilometres driven and/or of fuel costs' less often than they currently do. 11.5 percent of the firms, however, would consider compensating employees more often. Intended changes with respect to the provision of a company car to employees are also distributed differently: around 20 percent of the firms expects they will provide their employees with company cars less often due to the kilometre charge; only 5 percent of the firms intends to offer a car more often.

Whereas on average firms intend to provide company cars or 'fuel/kilometre cost compensations' somewhat less often compared to the current situation, the opposite is true as far as the other types of cost compensations and/or services are concerned. Around 19 percent of the firms intend to compensate employees more often for the costs of public transport, against nine percent that intend to compensate employees less often. For several services the differences between offering the compensation more or less frequently are even higher. Approximately 30 percent of the respondents intend to give employees a higher degree of flexibility in choosing their working hours and/or to allow them to work at home, against only four to six percent that indicates a lower degree of flexibility. Finally, with regard to residential relocation compensations the results

173 This is computed by adding the categories 'quite likely' (19.2 %), 'likely' (12.6 %) and 'very likely' (3.3 %).

174 This is computed by adding the categories 'quite unlikely' (9.9 %), 'unlikely' (13.0 %) and 'very unlikely' (11.8 %).

are less distinct. 16.7 percent of the firms intend to provide relocation compensations more often, compared to 10.5 percent that intend to do the opposite.

Overall, it can be concluded that, although a majority of firms choose not to alter the different compensations/services they currently offer to employees, a substantial share of firms intends to make changes with regard to 'compensations'/services. Car cost-related compensations, such as fuel/kilometre cost reimbursements or the provision of company cars, may on average occur less often when the kilometre charge will be implemented. On the other hand, public transport or relocation cost benefits will be given more frequently. Apparently, the most promising way for firms to try and compensate their employees for the increase in travelling expenses is to give them greater flexibility in adapting their working hours and allow them to work at home. An interesting topic for research, but one we could not carry out on the basis of the datasets we used, would be to see to what extent the intended compensations are in accordance with what employees expect. The results presented indicate that firms (though not all) plan to compensate their employees for the extra costs. If employees who currently receive a travel-related compensation expect they will be compensated for the additional costs, or if they do not expect to be compensated even though their firm is contemplating offering compensation, this may influence the (intended) behaviour of employees, which means that the results presented in chapters 5 and 6 may underestimate or overestimate what could happen in reality.

7.4.4 - Changes in the product/service prices and recruitment distance

In addition to changes in the current trip pattern and the compensations offered by firms to their employees as a result of road pricing measures, we measured two other 'short-term' behavioural reactions: changes in product/service prices and changes in the radius within which firms recruit their employees. The results of the frequency analyses we conducted are presented in Table 7.12, which was configured in the same way as before: it contains the percentages of each of the seven classes and the sum totals are presented at the bottom.

Table 7.12: intended changes in product/service prices and changes in the distance over which personnel is recruited.

Changes in product/service prices and in recruitment distance personnel due to the km charge	Increase product/ service prices	Recruit personnel more often in vicinity of the establishment
1: Extremely unlikely	10.7 % (52)	8.7 % (42)
2: Unlikely	11.1 % (54)	10.7 % (52)
3: Quite unlikely	4.1 % (20)	5.8 % (28)
4: Not unlikely/likely	23.3 % (113)	33.2 % (161)
5: Quite likely	20.8 % (101)	19.2 % (93)
6: Likely	20.6 % (100)	16.3 % (79)
7: Extremely likely	9.3 % (45)	6.2 % (30)
total unlikely (sum categories 1, 2, 3)	25.9 %	25.2 %
total likely (sum categories 5, 6, 7)	50.7 %	41.7 %

Table 7.12 shows that most firms (50.7 percent) think that it is likely that their product and/or service prices will be raised if the kilometre charge were to be introduced. As far as changes in the recruitment distance of employees are concerned, the results are quite the same. A majority of firms (41.7) intends to recruit personnel more often within the vicinity of the establishment. This, to save on employee compensation costs. In conclusion, although the questions may be a little suggestive (i.e. only questions regarding price increases/radius reductions were asked), it would appear that a large number of firms attempts to reduce the (additional) costs of road pricing measures by increasing prices and/or recruiting their employees closer to the settlement. This trend of trying to reduce (extra) costs due to the pricing measure corresponds with the intended changes in the trip pattern and in employee compensations we observed in sections 7.4.2 and 7.4.3. Firms in general want to make fewer trips during the more expensive peak hours. Moreover, firms intend to offer their employees more alternative compensations and possibilities, instead of expensive compensations or company cars: public transport compensations become more interesting, as does providing employees the possibility to avoid paying pricing costs by working more at home or change their working hours more often. In accordance with the firm's intention to recruit their personnel more often in the vicinity of their settlement (see Table 7.12) is the choice of firms to offer (current) employees more often a relocation compensation to move closer to work (see Table 7.11).

7.5 - Relocation probability due to pricing

7.5.1 - Introduction

This section focuses on the intention of firms to relocate due to the kilometre charge. Section 7.5.2 describes the relocation probability of firms on the basis of descriptive analyses. Subsequently, section 7.5.3 focuses on the factors influencing the relocation probability as a result of the charge. The influence of firm characteristics, firm perceptions and short-term behavioural change intentions is examined as well.

7.5.2 - Relocation probability of firms

Table 7.13 shows the distribution across the probability categories with regard to changing the settlement location due to the kilometre charge. Again, seven categories are distinguished, ranging from 'extremely unlikely' to relocate due to the pricing measure to 'extremely likely'.

Table 7.13: probability of relocating to another settlement due to the km charge

Probability of relocation	Probability
1: Extremely unlikely	41.0 % (199)
2: Unlikely	26.6 % (129)
3: Quite unlikely	4.5 % (22)
4: Not unlikely/likely	20.0 % (97)
5: Quite likely	4.3 % (21)
6: Likely	2.5 % (12)
7: Extremely likely	1.0 % (5)
Sum 5 to 7: quite to extremely likely	7.8 % (38)
Sum 6 to 7: (extremely) likely	3.5 % (17)

oreover, the sums of the categories (5 to 7 and 6 to 7) representing the highest probabilities are shown.

The average percentage of respondents who indicated that it is quite likely, likely or extremely likely that their firm intends to relocate is 7.8 percent. Somewhat less than half of them (i.e. 3.5 percent) considers it likely or extremely likely. To put the relocation probabilities as a result of road pricing measures into perspective, we also studied the probabilities in the light of the likelihood that firms may decide to relocate within two years anyway for whatever reason. Table 7.14 shows that a large part (i.e. 47 percent) of all the firms that indicated that they would likely relocate within that time frame specifically as a result of the kilometre charge are very likely to do so anyway. Approximately the same share of firms (53 percent) that consider relocating the settlement due to the charge indicated it was unlikely they were going to relocate within two years (for different reasons). Thus, on average firms that are already planning to relocate indicate that they are more likely to do so specifically as a result of the kilometre charge. As described in section 7.2, (mainly), two groups of firms were selected: firms operating in the business service sector or in the industrial sector. We found no significant difference with regard to their likelihood of relocation between the two sectors.

It may be interesting to compare these results with the expectations from literature in chapter 2 (sections 2.6.4.2 and 2.7) and to examine differences with the relocation probabilities for households, described in section 6.3.3. As we indicated in section 2.7, there are but a few studies that examined the influence of transport pricing policies on the relocation behaviour of firms. Moreover, most of these studies are based on modelling approaches. As far as we know, no empirical based research has been conducted to find out if firms are likely to relocate as a result of road pricing measures. The only study that has specifically looked at the likelihood for firm relocation is Muconsult (2000), who argues that the likelihood that firms will relocate in response to a road pricing measure is negligible, based on the fact that transport costs are only a small part of their operational costs. No quantitative indication is given of the share of firms that are expected to relocate. If, for whatever reason, the decision to relocate has already been made,

Table 7.14: probability of firms to change location due to pricing relative to the probability to relocate anyway

Cross tabulation		**Prob. change location 2 years (quite likely, likely, very likely =1)**		
Prob. change location due to road pricing (quite likely, likely, very likely =1)		0	1	Total
	0	398 (95.2 %)	49 (73.1 %)	447 (92.2 %)
	1	20 (4.8 %)	18 (26.9 %)	38 (7.8 %)
	Total	418 (86.2 %)	67 (13.8 %)	485

	Value	P-value
X^2	39.0	0.000
Kendall's tau-b	0.284	0.000

however, Muconsult (2000) expects firms to take pricing costs into account in selecting their new location. Additional to the Muconsult study, literature (see section 2.6.4.2) exists regarding the influence of accessibility/transport related characteristics on relocation decisions of firms. However, no unequivocal picture emerges from this literature with regard to the influence of transport-related characteristics such as travel distance, time and or costs. McQuiad *et al.* (2004), for example, state that not enough empirical evidence is currently available with respect to the influence of transport indicators, such as travel time and reliability of travel time. When the likelihood of firms relocating presented above is compared to what Muconsult (2000) expects, the results in this chapter seem to indicate that the influence of road pricing measures in this area is stronger. However, it is difficult to make a valid comparison, since Muconsult does not provide quantitative insights into the relocation probability of firms.

Additionally, one can also compare the likelihood of firms relocating as a result of a pricing measure with the residential and job-related relocation probabilities for households, which were described in section 6.3.3. The kilometre charge that was presented in the firm questionnaire is the same as kilometre charge variant 3E for households (see Table 3.5, section 3.4.4). The time-differentiated kilometre charge 3 that was presented to households consisted of six alternatives: three pricing levels and two different types of revenue use. Because a medium level price level was selected for the firm questionnaire and no clear price level or revenue use effects on the relocation probability of households were found, it appears to be legitimate to compare the firm relocation probability described above with the household relocation probabilities in the case of measure 3 in section 6.3.3. When we compare the two, we see that the observed probabilities for firms are higher than the residential relocation probabilities found for households. 7.8 percent of the firms indicated a quite high, high or extremely high probability of relocating, compared to 3.8 percent of the households. If only the response categories 'likely' and 'very likely' are selected, the difference is somewhat smaller: 3.5 percent for firms against 2.3 percent for households. The observed percentages for the firm relocation probabilities, on the other hand, are lower than the job relocation probabilities of households: 11.6 percent of the households indicated a quite high, high or extremely high probability; 6.4 percent a high or extremely high job relocation probability. A striking difference between the relocation probabilities of firms and households respectively is related to the probability of changing location within two years anyway. In the case of the firms, 47 percent (see also Table 7.14) of the firms that are likely to relocate as a result of the kilometre charge also have a (quite) high probability of relocating for different reasons. By contrast, as far as households are concerned, a majority (80 percent) of the respondents who indicated they were likely to relocate as a result of road pricing measures already have (quite) a high intention of relocating within two years. With regard to job relocation this is 72 percent. This seems to imply that firms are less dependent on existing plans to relocate when deciding whether or not to relocate as a result of road pricing measures.

To gain insight into the actual influence of the kilometre charge on relocation, relocation probabilities due to the charge must be compared to the probability that firms and households are planning to relocate anyway. For example, a small change as a result of road pricing measures may in fact be important if in a 'normal' situation very few firms or households relocate. On the other hand, if the percentage of people or firms intending to relocate is 'quite high', but a large percentage of them would do so anyway, the (relative) influence of the pricing measure is limited. Within the data sample we used, 13.8 percent of the firms have a quite high, high, or extremely high probability of relocating within two years for whatever reason. With regard to households these percentages are 23.5 and 30.3 percent respectively for residential and job-related relocations. Thus, the relocation probability for households is higher than for firms. Given the relocation probability percentage of firms as a result of the charge (7.8 percent) which is in between the percentages observed for households' residential and job relocation (respectively 3.8 and 11.6 percent) the influence of the kilometre charge on the relocation probability of firms seems to be relatively higher compared to the influence on household relocations.

Above, we reported that a substantial share (i.e. 47 percent) of the firms that intend to relocate due to the kilometre charge are also planning to relocate for different reasons (within two years). This means that comparing the firms in our sample who intend to relocate (for whatever reason) with the average percentage of all firms in The Netherlands that relocate each year may provide an indication of the effect a kilometre charge may have on the relocation of all (types of) firms in The Netherlands. Pellenbarg (2005) reports that each year around 7.5-8 percent of the firms in Holland relocates. This seems to match (i.e. marginally higher) the 13.8 percent of firms in the sample likely to relocate within two years: 13.8 percent in two years would quite likely lead to a maximum relocation level of around 7 percent per year. The percentage reported by Pellenbarg is based on an average over all firm sectors. Pellenbarg (2005) also represents the numbers of firms per sector that relocated on average over 2001 and 2002. If these numbers are related to the total amount of firms per sector in 2005 (see Dutch chamber of commerce, 2006) we can (roughly) estimate the relocation percentage per sector. By doing so we found that on average 7.8 percent of the firms in the advice/business service sector relocates each year. For the manufacturing industrial sector this is 6.1 percent. These two specific numbers (overall) are also quite comparable to the findings in the dataset we used (i.e. with the same kind of firm sectors incorporated). Given the observation that firms that intend to relocate anyway also indicate to relocate more often specifically as a result of the kilometre charge, it is possible that the observed relocation probability percentage in the sample (i.e. 7.8 percent) may be a relatively accurate reflection of reality (taken all types of firms into account). Keeping that in mind, the following section provides insight into several factors that influence the relocation probability of firms within the sample.

7.5.3 - Influencing factors for the relocation probability

To analyse the factors that influence the relocation probability due to the kilometre charge an ordered probit approach was used for the same reasons as described in sections 7.3.3.1 and 3.5.5: (i) the relocation probability is measured on an ordinal scale and (ii) the ordered probit model is the default model for analyzing categorical data within the used LIMDEP software. As was the case in chapter 6, at first sight it may seem a little odd to try to gain insight into factors explaining the relocation probability, given the low probability of relocation, presented in Table 7.13. However, from a statistical point of view it is possible because the relocation probability has been divided into seven classes. Estimating a model in this case not only takes the respondents who are likely to relocate into account, but uses the whole distribution of answers over the seven categories. Nevertheless, although it is defendable to estimate a model, we must also emphasize that estimation results will particularly be based on (the differences between) categories containing a substantially high number of cases (i.e. in this situation especially the classes representing a relatively lower probability of relocating).

Two different model estimations were made dependent on the number of response classes. In the original form the dependent variable has seven classes ranging from extremely unlikely (1) to extremely likely (7). Because especially the higher classes contain relatively few observations, which may influence the estimation procedure (see above), the seven classes were also re-classified into four categories, as was done for the household relocation variable in chapter 6 (see section 6.3.4.1): (i) an extremely low probability, (ii) a low probability, (iii) a rather low and not low/not high probability, (iv) a rather high, high, or extremely high probability. Both models are presented in Table 7.15.

When we compare the two models we see that the differences between the model results are small. Coefficient signs are the same and coefficient values vary only a little. Therefore, no explicit choice has to be made as to which model to use as a basis for describing influencing factors. In principle only factors that are significant with a reliability of at least 90 percent are taken into account, with the exception of the variable 'confrontation with congestion'. The reason for including this variable is discussed below. The most influencing explanatory variable in Table 7.15 is 'planning to change location within two years'. Firms that have (quite) a high probability of relocating within two years anyway indicated they were more likely to relocate as a result of road pricing measures too. This already emerged in section 7.5.3. In addition, three different settlement characteristics derived from the factor analysis, described in Appendix F, are explanatory: building characteristics and accessibility, flexibility of rules and contacts and thirdly the expansion and parking space. All three factors have a negative sign. This implies that firms that are relatively more satisfied with current settlement related characteristics are, as expected, less likely to relocate as a result of road pricing measures. The possible higher costs due to pricing do not seem to even out against the current satisfaction with the settlement.

Two spatial factors appeared to be significant as well: the geographical scale on which the firm predominantly operates with respect to sales and the region of The Netherlands where the settlement is located. Both variables have a negative sign. More locally and regionally oriented firms on average indicated a lower probability of relocating due to the charge. These types of firms may be tied to a specific region, which may mean that relocating over larger distances is not a viable option. The other spatial factor is the region in which the firm/settlement is located. With respect to location, The Netherlands was divided into four regions: north, south, east, and west. Firms within the sample that are located in the north and east displayed a lower relocation probability. This may have to do with the current cost-related situation, as firms located in the (more rural) north and east of The Netherlands (i.e. within the sample) pay lower costs for buildings/grounds and for transport. Because of the lower costs, extra costs due to pricing seem to have a less severe impact on these firms: they may have more 'financial room' to cope with the road pricing costs.

Three other significant variables are 'the number of settlements of the firm', 'the number of employees' and 'the extent to which the settlement is confronted with traffic congestion in the current situation'. Table 7.15 shows that settlements that belong to a firm with more than one settlement, have a relatively higher relocation probability. No unambiguous reason can be given for this finding. In advance one may even have expected the opposite to be the case. If firms with more than one settlement assume that travel costs increase due to the charge, they might prefer not to relocate or combine settlements because customers (or the settlement itself) may be reached more easily if sub-settlements are already strategically located (with respect to distance to customers). Combining settlements then could increase the overall distance to be travelled and as consequence raise the travel costs. On the other hand, it may be possible that current locations are not located optimally with respect to customers (or other relations). This then may lead to a higher relocation probability for these multi-settlement firms. Subsequently, in contrast to the negative coefficient sign observed for the variable 'number of settlements of the firm', firms with more than 100 employees were found to have a relatively lower relocation probability due to pricing. Possibly these larger firms are less cost-sensitive, find it more costly to relocate and/or experience more organizational problems than smaller firms, which reduces their relocation probability. However, these reasons are rather speculative.

The variable that represents the frequency with which the firms within the sample face congestion did not prove to be very significant. This variable was included because we expected that firms that face congestion regularly, may react differently to a charge compared to other firms. Firms that deal with congestion regularly may also benefit from a price measure where time gains are involved. Table 7.15 shows, however, that, although not significant at the 90 percent level, there seems to be an indication that firms that often face delays due to congestion on average indicated a higher relocation probability. These firms (in the sample) do not expect a higher reduction in congestion problems as a result of the charge than firms that are faced with traffic delays less often. Therefore, firms facing congestion may only see the downside (extra costs) of the charge. This may result in a somewhat higher, though not statistically significant, relocation probability.

The influence of the attractiveness and accessibility of a location on a firm's relocation probability was also tested. Respondents who rated the attractiveness of their current location lower, after compared to before the kilometre charge was presented, indicated a relatively higher relocation probability. The same applies to accessibility: firms that expect a reduction in the accessibility of employees due to the charge on average indicated there was a higher chance they would relocate their branch. Apparently, firms that feel the kilometre charge will affect them in a negative sense are more inclined to relocate. Finally, the influence of short-term trip changes was tested. The influence of short-term changes on the relocation probability was examined because one may expect that firms whose costs increase as a result of road pricing measures do not decide to relocate immediately. Short-term behavioural changes in most cases are easier to make and are therefore likely to be considered first when trying to reduce the costs (if this is necessary). Nevertheless, we found no 'strong' relationship between changes in the short-term trip behaviour and relocation. Only two significant effects occur. Firms that intend to make fewer business trips in the peak period, when the costs involved are highest, also indicated more often that they intended to relocate. On the other hand, firms that indicated they would reduce the number of car/lorry trips made for the transportation of goods indicated a comparatively lower relocation probability as a result of the charge. In conclusion, there does not seem to be a clear relationship between short-term trip changes and relocation effects due to pricing: only few short-term behavioural trip changes seem to influence relocation decisions of firms and the two significant factors have an opposite sign.

In section 7.5.2 the relocation probability of households as a result of road pricing measures was compared to that of firms. Since the current section focused on explanatory variables for relocation, it may be interesting to briefly compare the signs of factors that emerged as being

Table 7.15: explanatory variables for the firm relocation probability due to the km charge

Change settlement location firm: explanatory variables	M1: relocation probability 7 classes		M2: relocation probability 4 classes	
	Coeff.	P-value	Coeff.	P-value
Constant	0.1677	0.2080	0.1403	0.3012
dummy planning to change location within 2 years	0.9784	0.0000	0.9456	0.0000
dummy number of settlements of firm (settlements > 1 = 1)	0.2644	0.0129	0.2583	0.0167
dummy number of employees of firm (employees ≥ 100 =1)	-0.2561	0.0314	-0.2484	0.0393
dummy geogr. operating scale settlement (municipal, regional level = 1)	-0.2777	0.0274	-0.2655	0.0373
dummy region settlement (north, east of The Netherlands = 1)	-0.2570	0.0135	-0.2266	0.0320
dummy confrontation with congestion (quite often to extremely often =1)	0.1450	0.2522	0.1838	0.1551
dummy change in location attractiveness due to km charge (decrease = 1)	0.2830	0.0066	0.2775	0.0086
dummy change accessibility employees due to km charge (decrease = 1)	0.2537	0.0246	0.2432	0.0340
dummy business trips in peak period due to km charge (decrease = 1)	0.1748	0.0979	0.2223	0.0382
dummy trips for goods by car due to km charge (decrease = 1)	-0.4901	0.0400	-0.5355	0.0264
dummy building characteristics and accessibility (regr. coeff. ≥ 1)	-0.2984	0.0480	-0.3132	0.0401
dummy rules and contacts (regr. coeff. ≥ 0.9)	-0.3608	0.0181	-0.3675	0.0172
dummy expansion space and parking (regr. coeff. ≥ 0.5)	-0.3428	0.0034	-0.3544	0.0028
μ_1	0.7787	0.0000	0.7799	0.0000
μ_2	0.9277	0.0000	1.8987	0.0000
μ_3	1.9083	0.0000		
μ_4	2.3853	0.0000		
μ_5	2.9789	0.0000		
N (number of respondents)	485		485	
Log likelihood (convergence)	-647.4		-555.9	
X^2	116.1		112.3	

significantly explanatory both for household and for firm relocation as a result of road pricing measures. Roughly speaking, differences on three characteristics can be evaluated[175]: the region in which the firm or household is located, the extent to which households/firms face traffic congestion and finally the intention of households/firms to make changes in their current trip pattern due to a (road) pricing measure. Chapter 6, section 6.3.4.2, showed that respondents living within a region with congestion problems (i.e. roughly the western part of The Netherlands) have a lower probability of changing their job/house location due to pricing than households living within the more 'rural' regions. For firms the opposite was found. Firms located in the more rural regions (the north and east) were found to have a lower relocation probability due to the charge.

175 This can be done because only these three (partial) mutual variables proved to be explanatory both for households and firms.

A possible explanation for households having a lower relocation probability is that the higher number of (alternative) activities available within short distances in the west of the country offers respondents a better possibility to reduce the costs. As described above, lower relocation probabilities of firms in rural areas may be attributed to the on average lower firm-related costs (e.g. building, site and probably transportation costs) in these rural regions. Due to the lower costs, firms may be better able to cope with (extra) costs involved in a (road) pricing measure. Finally, the influence of short-term trip changes on a household's or firm's choice to relocate as a result of road pricing measures can be evaluated. Households that indicated they would make changes in their trip behaviour due to a (road) pricing measure on average also showed a higher relocation probability. As far as firms are concerned, however, no strong relationship between short-term and long-term changes was found.

In summary, firms that already have (quite) a high probability of relocating within two years, firms that consist of more than one settlement, firms that perceive a decrease in the attractiveness of their location due to pricing and businesses that expect a decrease in the accessibility of employees indicated a relatively higher relocation probability as a result of the kilometre charge. On the other hand, a relatively lower relocation probability was observed for firms that score better than other firms on building characteristics and accessibility, on the flexibility of rules and contacts and on expansion and parking space. In addition, more locally and regionally oriented firms with respect to sales, firms that are located in the north and east of The Netherlands and firms with more than 100 employees also seem to have a lower inclination to relocate due to a kilometre charge. Finally, no strong relationship between short-term behavioural changes, such as intended employee compensations and/or trip pattern changes, and long-term relocations was found.

7.6 - Firm clusters and their behaviour

In the previous section ordered probit analyses were conducted to gain insight into factors explaining differences in the relocation probability change (section 7.5.3) due to a kilometre charge. Although Table 7.15 showed which factors are significantly explanatory, the analysis did not make clear whether or not specific groups of firms exist that behave in a certain way. Such possible existing groups or clusters may provide additional insight into firm's behaviour, possibly elucidating and unravelling the sometimes seemingly complicated (not always unambiguous) relations observed in the previous section(s). This section tries to determine whether or not clear groups of firms with a specific behaviour can be distinguished. Three types of behavioural changes as a result of the kilometre charge are taken into account: changes in employee compensations, changes in the trip pattern of firms and the relocation probability of firms. The approach we chose to derive insight into possible clusters of firms behaving in a certain way was divided into two phases. The first phase aimed at defining clusters that are clearly distinguishable or can easily be labelled. This is described in section 7.6.1. In the second stage the resulting clusters are used as independent factors to explain differences in firms' intentions to change their behaviour as a result of the kilometre charge. The results of this second stage are reported in section 7.6.2.

7.6.1 - Clustering of firms

Two important choices have to be made when clustering firms within the sample: the clustering technique and the selection of characteristics on the basis of which the firms are grouped. There are three main cluster analysis methods: hierarchical cluster, K-means cluster and two-step cluster analysis (Garson, 2006; SPSS, 2006). Since most variables within the dataset are categorical and because the dataset is quite large (485 respondents) the two-step cluster analysis is the right technique to use. An additional advantage of the two-step analysis compared to, for example, the hierarchical cluster method, is that the two-step cluster method automatically selects the most appropriate number of clusters whereas the researcher has to decide this in the case of using hierarchical cluster analysis. For a complete overview of the criteria involved in selecting the appropriate type of cluster analysis in all kinds of situations, see Garson (2006) and SPSS (2006).

The second choice has to do with the selection of characteristics on the basis of which the firms are to be clustered. As described in section 7.2 the dataset contains information about a relatively wide range of firm characteristics. Combining all these characteristics into one cluster analysis does not yield any substantial clusters. Secondly, we examined whether or not firms can be clustered easily on the basis of the explanatory factors for the relocation probability presented in Table 7.15. Clustering the firms within the dataset on the basis of these explanatory factors does not lead to clearly distinguishable clusters. This means that no clusters of firms emerge which explain the differences in relocation probability as a result of road pricing measures. Subsequently, a somewhat more systematic approach was followed to determine whether or not clusters of firms exist explaining differences in the intended changes of behaviour due to the kilometre charge. Thereby, the focus was not limited to studying differences in the relocation probability. Short-term behavioural changes (i.e. employee compensation changes and trip changes) were also taken into account (see section 7.6.2). On the basis of the 'theme/topic' of the variables in the dataset, four 'theme classes' were distinguished (see Table 7.16): (i) firm socio-characteristics, (ii) current accessibility and location characteristics/perceptions, (iii) the expected changes (i.e. cost, location attractiveness) as a result of road pricing measures and acceptability of the charge, (iv) the intended short-term changes in the behaviour of firms. The variables in each class (see second column Table 7.16) were then used to cluster firms. This means that four cluster analyses were carried out: one for each group of questions. Two methods exist that can be used to determine the appropriate number of clusters. We used the Schwarz Bayesian Criterion (instead of Akaike Information Criterion), as it is the first option available in SPSS. Moreover, there does not seem to be a strong methodological reason to prefer one method above the other. For all four groups of questions, the two-step cluster analysis came up with a division in two clusters as the most appropriate solution. These clusters, including what they represent, are shown in the third column of Table 7.16[176]. The two clusters (within a group) can often be clearly labelled on the basis of differences in the means for the different variables. Within group 1, one cluster consists only of industrial firms (with generally speaking fewer settlements) that operate on a higher geographical scale compared to the other cluster. With regard to the second group, a distinction can be drawn between firms in one cluster scoring relatively higher on all location related factors and on accessibility. Additionally, on the basis of the characteristics in group 3, one cluster emerges

176 Although clusters can be distinguished and labeled quite easily, the standard deviations of the means per cluster are high. As a consequence, the differences in means between two clusters (per group of characteristics) are often not significant.

that contains firms that have a more positive attitude towards the kilometre charge. However, distinguishing between the two clusters on the basis of the characteristics in group 4 is somewhat more difficult. The firms in one of the two clusters seem to be relatively more willing to change their current behaviour regarding employee compensations and trips made. Firms in this cluster more often choose to compensate employees for public transport and relocation costs and intend to offer their employees the possibility to adapt their working hours or to work at home more often. Additionally, these firms have a higher intention to change trips. Although this intention is higher they do not necessarily change trips in order to mitigate monetary costs. They choose

Table 7.16: firm clusters created on basis of different groups of firm characteristics

Group characterization	**Characteristics**	**Cluster 1 (compared to 2)**
Group 1: firm socio-characteristics	• Number of settlements firm • Number of employees per settlement • Branch (industry or business) • Geographical orientation firm with respect to customers • Region settlement in The Netherlands	*Industrial firms, working on a higher spatial scale, with fewer settlements* • Preliminary industrial firms, fewer settlements, somewhat more employees per settlement, higher geographical operating scale
Group 2: current settlement location scores and accessibility of settlement	• Current accessibility of firm by car/ Public transport/bike • Current traffic congestion problems firms • Attractiveness location • Score on 19 (other) location related factors	*Higher score on current location factors and on accessibility*
Group 3: expected changes in costs, accessibility and location attractiveness firms due to the km charge	• Expected costs change (transportation, business, commute traffic) • Expected congestion change • Expected changes in location attractiveness • Acceptability charge • Perceived accessibility changes	*More positive attitude towards pricing* • Expected lower increase of costs, higher expected congestion reduction due to charge, lower decrease in attractiveness of location due to the km charge and a higher acceptability of the charge
Group 4: intended changes in trip behaviour firms and in employee compensations due to the km charge	• Intended changes in employee compensations • Intended changes in trip behaviour	*Firms with relatively higher change intention* More alternative employee policies: • Relatively less often compensation of km/fuel costs and offering a company car less often • Offer employees relatively more often compensation for public transport and relocation and offer more regularly flexible working times and possibility to work at home More trip changes: • Transportation trips: more in general and more in peak and off-peak • Business trips: fewer trips in general and more in peak period • More use of ICT as substitute for current trips

on average more often to reduce the number of business trips compared to the current situation, but decide on the other hand to make more trips for transportation of goods.

To generalize the results even further, variables of the four topic classes were systematically combined (i.e. over groups). Subsequently, cluster analyses were carried out on these combined 'theme' groups. However, this procedure did not lead to interpretable clusters.

7.6.2 - Differences in behavioural changes between firm clusters

In this section we examine whether the clusters presented in the third column of Table 7.16 may explain differences in the intended behavioural changes of firms due to the kilometre charge. A distinction is made between short-term changes (i.e. alterations in employee compensations and trip behavioural changes) and long-term changes (i.e. the relocation probability). An exception is made for the fourth group (see Table 7.16). Because in this group firms were clustered on the basis of short-term changes, we only look at differences in long-term behaviour there.

With respect to clusters created using characteristics in group 1, cross tabulations with Kendall's tau as association measure indicate that firms that belong to the cluster labelled 'industrial firms, working on a higher spatial scale, with fewer settlements' intend to make more transport trips (general, in peak and outside peak) and more business trips (general and inside peak) compared to firms in the other cluster (cluster 2) when pricing is introduced. Additionally, these firms (first cluster) are more willing to compensate their employees for (extra) kilometre or fuel costs. No significant relationship with relocation was found, however. Between the two clusters in group 2 also significant behavioural differences emerge. Firms with a better current accessibility (of their settlement) and with higher location-related (attractiveness) scores have a higher intention to make more trips due to charge, and have a lower relocation probability than firms within the 'opposite cluster. As expected, firms that indicate they have a better accessibility and a more attractive location, and score better on all kinds of (other) location-related factors also are less inclined to relocate due to the price measure: they are already (more) satisfied with their location. Furthermore, firms that have a more positive attitude towards the charge (i.e. first cluster in group 3) are less likely to reduce employee compensations or relocate. However, no clear relationship with trip changes was found. Finally, firms that are more inclined to change their behaviour in the short run (i.e. first cluster in group 4) also indicated a relatively higher probability of relocating.

This section used cluster analyses to gain greater insight into which types of firms are more or less likely to change their behaviour due to the kilometre charge. First of all, firms were clustered on the basis of the (single) explanatory factors for the relocation probability of firms observed in Table 7.15 (section 7.5.3). This procedure did not lead to clearly distinguishable clusters. This seems to point out that no groups of firms with certain (combined) characteristics exist that primarily explain the differences in the relocation probability as a result of the kilometre charge. Instead, it is the individual characteristics of a firm that seem to explain the differences in behaviour. Nevertheless, cluster analyses carried out on thematic groups of variables did provide some additional insight into which types of firms are more or less likely to change their short-term and long-term behaviour in response to road pricing measures. With respect to relocation, there seems to be a strong tendency that firms that are more positive about pricing (i.e. expect more positive effects) and firms that currently score well on all kinds of location and accessibility characteristics have a lower probability of relocating due to pricing.

7.7 - Conclusions and methodological limitations of the research

7.7.1 - Conclusions

On the basis of a questionnaire held among 485 firms operating in the industrial and business service sectors, in this chapter we examined to what extent road pricing influences the perceived accessibility and short-term and long-term (i.e. relocation) behaviour of firms. With respect to the perceived change in accessibility and the relocation probability, analyses into explanatory factors were conducted as well. We did not do this for short-term behavioural changes because our main focus in this thesis is on the effects of pricing policies from a geographical perspective. As such, geographical accessibility and relocation are considered the key topics.

Changes in accessibility as a result of the kilometre charge were measured in two ways. In the first approach, firms had to rate their accessibility with and without the introduction of the kilometre charge. Thereby, three 'types' of accessibility were distinguished: accessibility settlement for supply and transportation of goods, for employees and the accessibility of the settlement for customers. On average, firms expect all three types of accessibility to decrease a bit due to the kilometre charge. The mean decrease in accessibility scores over all three types of accessibility (measured on a scale from 1 to 10) is eight percent. However, most firms (approximately 67 percent) envisage no accessibility change. Only around five percent expect an accessibility increase as a result of the charge. In the second approach, accessibility was defined first (see section 7.3.2). Subsequently, respondents had to indicate their expected change in accessibility due to the charge in four related questions. In the first question no explicit benefit of the charge was formulated. The other three questions assumed benefits in the form of an improvement of the travel time reliability, a 25 percent and a 50 percent decrease in delay time respectively. In the case where the benefits were not formulated, firms (i.e. 14 percent) on average expect a (small) decrease in accessibility as observed in the first approach. Eight percent expect an increase and 78 percent think there will be now change. These figures (i.e. no change and increase) are somewhat higher than in the first approach. However, in line with what we found in the first approach firms on average indicated a small accessibility decrease. By contrast, if benefits (such as travel time or reliability gains) are stated explicitly, firms on average perceive an increase in accessibility. Although a substantial part of the firms still expect there will be no change, 24 percent expects a (small) accessibility improvement if the reliability in travel time improves due to the charge. If travel time benefits are assumed, around 40 percent expect an accessibility increase. Thus, it would appear that the perceived change in accessibility of firms as a result of the kilometre charge is rather dependent on whether or not guarantees can be given regarding improvements in the current travel time and/or in the reliability of travel time. In addition to these time benefit factors, ordered probit estimations showed that several firm characteristics explain differences in the perceived change in accessibility as a result of the kilometre charge. Firms employing 50 or more employees and firms that perceive their settlement to score relatively better (than other firms) on several settlement cost, employee cost and trip cost-related aspects also indicated a relatively higher improvement (or lower decrease) in accessibility as a result of the charge. On the other hand, businesses in the industrial sector, firms working mainly on a municipal scale with respect to customers/sales and firms that score better than others on settlement location and accessibility-related aspects expected a relatively lower improvement (or higher decrease) in accessibility as a result of the kilometre charge.

Subsequently, we studied the intended behavioural changes. The following types of short-term behavioural changes were distinguished within this chapter: changes in the trip pattern of firms, alterations in employee compensations or services offered to them and, finally, changes in product prices and in the radius within which employees are recruited. Around 30 to 40 percent of the firms considers making changes in their current trip pattern by car (or lorry) in response to the kilometre charge presented to them. Changes with regard to the timing of the trips (to avoid driving during the more costly peak hours) seem more likely to be made than choices to reduce the overall frequency of travelling by car/lorry. In addition, changes are more likely to affect business trips than trips involving the transportation of goods, which indicates that transporting goods is a more vital element, and one in which there is less room for modifications. Nevertheless, most firms that choose to adapt current trips intend to do so only to a limited extent. Besides more 'regular' changes in the trip pattern, such as time changes, the use of ICT also seems to be a promising alternative to save extra costs for business or commute traffic due to pricing.

With respect to employee compensations or services, changes due to the kilometre charge can be expected too. Although the majority of firms choose not to alter the different compensations/services they currently offer to employees, still a certain share of the firms (around 30 percent) does intend to make 'compensation/service' changes. Car cost-related compensations, such as fuel/kilometre cost reimbursements or the offering of a company car, may be provided relatively less often to employees when the kilometre charge will be implemented. On the other hand public transport or relocation cost benefits will be offered more frequently. Seemingly the most promising way for firms to come to meet employees in possibly higher transport costs as a result of the charge is to provide employees with more flexibility in their working times and in their ability to work at home. Finally, changes in product prices and in the distance over which employees are recruited were only superficially examined. It seems that a large number of firms tries to mitigate (extra) costs as a result of road pricing measures by increasing prices (i.e. approximately 50 percent) and/or by recruiting employees in the closer vicinity of the settlement (i.e. around 42 percent).

In addition to changes in the perceived accessibility and in the short-term trip pattern of firms, the relocation probability due to the kilometre charge also was a topic of research. Around eight percent of the firms pointed out that it is reasonably likely that their firm will relocate due to the kilometre price measure. Roughly half of these firms indicated they would likely relocate within two years anyway. This may imply that especially firms that already have (quite) a high intention to relocate are 'encouraged' even more to do so by the introduction of a road pricing measure. The relocation probability for firms was found to be higher than the residential relocation probability of households due to a time-differentiated kilometre charge (see chapter 6), i.e.: approximately four percent. However, the job relocation probability of households was higher: 11.6 percent. Given the lower share of firms that relocate on a yearly basis compared to households, it may be concluded that road pricing has a higher influence on firm than on household relocations. Additional to descriptive analyses, ordered probit models were estimated to gain insight into factors explaining the differences in the relocation probability. Apart from the influence that firms with a high probability of relocating anyway have a higher probability to relocate due to the charge, some other characteristics proved to be significant as well. Firms that consist of more than one settlement, firms that perceive a decrease in the attractiveness of their location due to pricing and businesses that expect a decrease in the accessibility of employees indicated a relatively higher relocation probability due to the kilometre charge. On the other hand a relatively lower relocation probability was observed for: firms that score better than other firms on building characteristics and accessibility, firms that perceive rules/laws and contacts to be flexible and firms that score higher on expansion and parking space. Moreover, firms that tend to operate on a more local and regional level with respect to sales, firms that are located in the north and east of The Netherlands and firms with more than 100 employees also seem to have a lower inclination to relocate in response to a kilometre charge. Finally, no strong relationship was found between short-term behavioural changes, such as intended employee compensations and/or trip pattern changes, and long-tem relocations.

In addition to studying which single (firm) characteristics explain differences in the observed perceived change in accessibility or in the relocation probability of firms due to the kilometre charge, cluster analyses were undertaken. These cluster analyses aimed to determine whether or not clear groups of firms with a specific behaviour could be distinguished. These analyses pointed out that no clear groups of firms exist that clarify the differences in the perceived change in accessibility or in the relocation probability as a result of the kilometre charge. Instead merely single firm characteristics seem to explain the differences. Nevertheless, partly additional to the ordered probit analyses, the cluster analyses provided some insight that firms that are more positive about pricing (i.e. expect more positive effects) and firms that currently score already good on all kinds of location and accessibility characteristics have a lower probability to relocate as a result of road pricing measures.

7.7.2 - Methodological limitations of the research

Although the results described in this chapter have provided an initial insight into the intended behavioural changes of firms as a result of road pricing, for budgetary reasons and to keep the length of the questionnaire within acceptable limits we were unable to investigate certain possibly relevant aspects, in particular with regard to trip and location changes.

For one thing, we were unable to examine short-term changes in trip patterns as thoroughly as we did in chapter 5. This has to do with the way questions regarding this area were asked. For example, respondents could only indicate the extent to which they wanted to change their trip pattern on an ordinal scale, whereas households could indicate intended trip pattern changes more exactly, i.e.: the exact number of trips changed per period. In addition, the household survey was constructed in such a way that respondents could not choose to adapt more current car trips than they actually make: the sum of the alternatives that were selected had to be equal to the number of trips that would be changed. By contrast, as we discussed in section 7.4.2, for budgetary reason this approach was not applied in the firm questionnaire. This means that respondents in principle could choose unrealistic combinations, for instance reduce the overall number of trips and at the same time increase the number of trips when considering the peak and off-peak periods.

A further shortcoming of the firm questionnaire with regard to the short-term and long-term behavioural changes was that the probable benefits of road pricing measures were not formulated explicitly in the survey. However, section 7.3.2 showed that if respondents are explicitly confronted with possible travel time (or travel time reliability) benefits that may occur due to a toll, they regard their perceived change in accessibility as a result of road pricing measures in a more 'positive' way. Of the respondents in the dataset, only 18 percent expects it to be quite likely, likely or highly likely that traffic congestion problems will be reduced as a result of the kilometre charge. Of this group a mere 5.7 percent assumes improvements are likely or highly likely. This perhaps points out that in answering the questions regarding behavioural changes most respondents assumed no travel time benefits would occur. If quantitatively expressed benefits would have been shown to respondents, intended trip changes and relocation probabilities could have found to be different. Therefore, in a more ideal situation the influence of travel time (and reliability of time) benefits would have been systematically included when studying intended behavioural changes of firms. Moreover, ideally it is not preferable to answer the behavioural change questions for one charge level only. Different price levels may have different behavioural effects. The same is true for different types of measures, such as spatial differences due to a cordon compared to a kilometre charge (as was shown in chapter 6).

Similarly, there are some additional location-related effects we could not investigate that are worth mentioning. It would have been interesting to learn more about the exact spatial consequences of a charge. For example, if a firm intends to relocate, where is it likely to end up? Is it likely to locate (or stay) in the economic core of The Netherlands (i.e. the Randstad[177]), e.g. due to an expected congestion reduction, or will it move to a more rural environment or choose to locate elsewhere? Another interesting question is whether firms try to reduce (or maybe increase, in cases where time gains are involved) their distance to customers, suppliers and/or employees. Additionally, it would also be interesting to study the influence of a price measure at various stages of the relocation process. In chapter 6, for example, a distinction into two phases was made: the decision to relocate and the choice of location. With regard to households, a road pricing measure may affect both the decision by firms to relocate and their choice of location. According to Van Dijk and Pellenbarg (2000) and McQuiad *et al.* (2004), for example, transport-related aspects are especially important in business relocation when the decision to move has already been made.

In conclusion, there were a number of aspects that could not be studied in great detail in this chapter either for budgetary reasons or because we had to keep the length of the questionnaire within acceptable limits. The decisions which elements to include in the survey were made in consultation with partners within the multi-disciplinary project MD-PIT[178].

177 The Randstad area, which is situated in the western part of The Netherlands, and which forms the economic core of the country, also suffers most from traffic congestion.

178 This is short for 'a Multi-Disciplinary study of Pricing policies In Transport' (see also section 1.1 or Appendix A).

8 - Summary and conclusions

8.1 - Introduction

Road pricing policies are increasingly considered or even implemented in urbanised areas around the world, with the aim of reducing congestion, maintaining the accessibility of urban regions and minimising negative environmental effects of road traffic (Van Wee, 1995; De Wit and Van Gent, 1998; Verhoef, 2000). An additional motivation is the generation of revenues that can be used to build and maintain infrastructure. Focusing on the reduction of congestion, road pricing policies in several countries are seen as a potentially promising measure to reduce congestion problems (Tfl, 2003; Phang and Toh, 1997). This is also the case in The Netherlands. However, although road pricing is an important issue in the Dutch political debate (Nationaal platform anders betalen voor mobiliteit, 2005), until now no such type of measure has been introduced. It is expected that public acceptance will play a vital role in the decision whether or not to implement a road pricing measure. In The Netherlands, this public acceptability is low (Rienstra *et al.*, 1999). In part this is as a result of the fact that little is known about the possible effects of a charge. There may be a feeling that a charge would only lead to 'paying without any positive effect'. It is clear that getting a greater insight into (traffic) effects of a transport charge is important.

Pricing measures may affect both the behaviour of households and firms in the short-term as well as in the longer-term. In the short-term, households and firms may decide to make changes in the trip pattern (e.g. change trip frequencies, departure times, mode of transportation etc., depending on the type of charge). In a longer-term they may change their activity locations. Households, for example, can choose a new residential and/or working location to reduce transport costs, or they may decide to live or work at a more preferred place (e.g. in case more preferred locations come within reach as a result of possible travel time gains). Moreover, road pricing can have an influence on the location decisions of firms and it may even serve as a trigger for relocation. Possible important behavioural changes with regard to firms that may be carried out either in the short-term or in the long-term, and that may also influence a household's behaviour, include changes in the human resource policies of firms: firms can, for example, decide to change their policies regarding the compensations and fringe benefits they offer (new) employees. In general, short-term changes are more likely to be made than longer-term changes. If short-term changes cannot be made satisfactorily, households and firms can choose to relocate.

This thesis focused on road pricing (effects) from a transport geographical perspective. This 'geographical perspective' was translated into two different research lines, the first of which was concerned with geographical accessibility. Whereas economic analyses are particularly suitable to determine average welfare effects of road pricing measures, they do not provide insight into how the accessibility of varying types of people at different locations is influenced by road pricing. From a policy evaluation point of view it may be interesting to determine such differentiated accessibility effects before actually implementing a pricing measure. This can, for example, be done in addition to assessing general welfare effects. Geographical accessibility outcomes may then help further tailor a (planned) road pricing measure.

Despite the possible advantages of using geographical accessibility as a policy evaluation tool, geographical accessibility indicators have, to the author's knowledge, not been used to evaluate road pricing effects. This may in part be caused by the fact that geographical accessibility measures in their basic form are not directly applicable to road pricing. In practical applications travel time or distance-based accessibility indicators are most often used. To assess the accessibility effects as a result of road pricing, however, a transport cost-based accessibility indicator is needed. The question is, however, how such effects can 'best' be determined. An added value of this thesis is that it explored what geographical accessibility measures are particularly suitable to determine the accessibility effects as a result of road pricing. In addition, necessary refinements to accessibility measures were acknowledged and practical and affordable ways to compute accessibility effects as a result of pricing were determined. More specifically, the goal associated with the first research line in this thesis is:

To provide (more) insight into how to model realistic geographical accessibility effects due to pricing measures by (i) theoretically assessing the choice of suitable accessibility measures, the specification of the resistance function that is needed and the modelling processes to be considered and by (ii) practically determining the sensitivity of the modelled accessibility effects to varying price measure or (other) accessibility measure-related aspects.

On the basis of state-of-the-art models the analysis aimed at providing some insight into which types of price measures (and price levels) lead to higher accessibility gains or lower accessibility losses compared to other measures. Moreover, the analysis was intended primarily to find out more about how important it is to differentiate the generalized transport cost function towards various cost-related and personal characteristics, and whether it is important to take more than one accessibility measure (and resistance parameter) into account when realistic accessibility effects due to road pricing have to be determined.

Whereas the 'first line of investigation' of the thesis focused on geographical accessibility, the second approach aimed to gain greater insight into the behavioural intentions of households and firms as a result of road pricing. The thesis focused specifically on the longer-term behavioural (relocation) effects of households and firms as a result of road pricing. However, short-term (trip) changes were also analyzed since, as indicated before, short-term and longer-term behavioural changes are expected to be interdependent. With respect to the second research line the goal is:

To provide insight into the behavioural effects, especially (re)location choices of households and firms, due to or under influence of (different) transport pricing measures.

This behavioural effect study has been innovative in several ways. Firstly, people's and firm's intentions to change their behaviour as a result of road pricing were studied based on empirical (stated preference) data. Thus far, such empirical evidence is limited in literature. Secondly, this thesis focused specifically on (longer-term) location effects as a result of road pricing, which to date have received little scientific attention. Thirdly, these location effects were examined in addition to short-term behavioural trip pattern changes for the same respondents. To the author's knowledge this is the first research that studies both these short-term and longer-term behavioural effects. Two other innovative aspects are that (i) behavioural change intentions were systematically studied for a range of different road pricing measures with varying price levels and revenue use configurations and (ii) with respect to the short-term, behavioural effects were studied not only for commuting, but also for other trip purposes: social trips, other (than commuting or social) trips and shopping trips (as a special purpose falling into the category of 'other' trips). Finally, this thesis adds to the existing body of knowledge by thoroughly examining which types of people and firms (with their characteristics) are more or less inclined to change their short-term and longer-term behaviour. This was analyzed by using state-of-the-art statistical estimation techniques.

To achieve both research aims four research questions were addressed.

Accessibility-related

1. To what extent are current geographical accessibility measures applicable for modelling accessibility effects due to road pricing and which aspects and processes have to be taken into account for modelling realistic accessibility effects due to road pricing?
2. To what extent are geographical accessibility measure outcomes under road pricing conditions sensitive to varying cost (i.e. type of price measure, price level, specification of generalized transport cost function) and non-cost related aspects (i.e. accessibility measure, resistance parameter and network detail), and what implications for modelling geographical accessibility effects due to road pricing can be derived from these analyses?

Behavioural, especially location related

3. To what extent do (road) pricing policies influence short-term trip/travel patterns and (re)location, especially work and residential location, choices of households?
4. To what extent does (road) pricing influence the perceived accessibility and short and long-term behaviour of firms?

In section 8.2 the results are summarized, answering these four research questions Section 8.3 presents the most important conclusions. Recommendations are made in section 8.4, and in section 8.5 directions for further research are provided.

8.2 - Summary of results

This section provides a summary of the results. Section 8.2.1 addresses the results with regard to modelling geographical accessibility effects due to transport pricing measures, and answers research questions 1 and 2. Section 8.2.2 focuses on the intended short-term and long-term behavioural changes of households as a result of various pricing schemes (i.e. research question 3). Perceived accessibility and intended behavioural changes of firms are addressed in section 8.2.3 (research question 4).

8.2.1 - Modelling geographical accessibility effects due to transport pricing measures

To achieve the accessibility-related goal two research questions were formulated within this thesis. The first question was answered in chapter 2:

To what extent are current geographical accessibility measures applicable for modelling accessibility effects due to road pricing and which aspects and processes have to be taken into account for modelling realistic accessibility effects due to road pricing?

Several types of geographical accessibility measures can be distinguished such as: infrastructure-based, location-based, person-based and utility-based measures (see Geurs and Van Wee, 2004). All these measures have their own specific characteristics making each measure vary in terms of their suitability for being used in particular situations. On the basis of five criteria the suitability of different types of accessibility measures to be used for modelling (realistic) accessibility effects due to road pricing measures was assessed (see section 2.5.2 for a motivation for using these criteria): (i) realism of outcomes, (ii) ability to model on a regional scale, (iii) (low) data requirements, (iv) method transferability to different regions and (v) interpretability (and policy relevance). *Overall contour and potential accessibility measures that can be assigned to the class of (classical) location-based measures score best on the formulated criteria.* Although these two measures in essence do well, they have to be specifically tailored to be able to model 'realistic' accessibility effects as a result of road pricing measures.

Monetary toll costs can be seen as an extra resistance to reach a certain destination, in addition to other resistance components such as travel time. *A generalized transport cost function approach can be used to take the most important resistance components such as travel time and toll costs, into account.* In the generalized transport cost function travel time can be translated into financial terms by multiplying travel time with a value of time (VOT). A toll cost component can then be added to derive one generalized transport cost function. Thus, at first sight modelling the geographical accessibility effects as a result of road pricing appears to be easy. However, appearances may be deceptive. *In order to model realistic accessibility effects as a result of road pricing measures it is important to:*

- Differentiate the generalized transport cost function towards (VOT) influencing factors;
- Take the (short-term and long-term) behavioural effects due to road pricing into account
- Acknowledge the occurrence of revenue reinvestments and differences between 'objective' and 'perceived' accessibility.

These aspects and the importance of taking them into account are discussed below.

Differentiate generalized transport cost function

Using only one VOT results in a generalized transport cost function that is easy but not realistic. People with different characteristics value travel time savings in different ways and thus may be affected differently by road pricing measures. People with higher incomes, for example, appear to have higher VOT's. Therefore, *to derive realistic accessibility effects the VOT's used in the generalized transport cost function have to be differentiated according to important VOT-influencing factors such as income*[179]. Besides possible travel time gains, road pricing measures may affect the reliability of travel time and as a consequence the reliability of scheduling activities. Values of reliability (and values of schedule delay) can be used to enhance the generalized transport cost function further, making accessibility outcomes more realistic.

179 This differentiation towards income was not applied in chapter 4, since in that chapter the aim was to study the sensitivity of accessibility effects due to road pricing rather than to determine realistic accessibility effects for different groups of people themselves.

Behavioural effects
In modelling accessibility effects a distinction can be made between first-order and second-order effects. This is visualized in figure 8.1, which is a simplified version of the conceptual model presented in chapter 2, section 2.8. A road pricing charge influences the generalized transport cost function and as a consequence accessibility. This can be regarded as a first-order effect. For every group of people with the same generalized transport cost function and living at the same location, the first-order accessibility change is the same. As a result of the change in (perceived) accessibility short and/or long-term behavioural changes can occur, which influence the accessibility via the feedback loop. Depending on the type of pricing scheme, car drivers in the short-term can decide to change their departure time, route, mode of transportation and/or trip frequency. These adjustments result in travel time changes. Furthermore, relocations are an example of long-term behavioural changes. All these behavioural changes can be seen as second-order effects. Individuals with the same generalized transport cost function may have different behavioural reactions, if they choose to change anything at all. This results in differing accessibility effects. It is important, therefore, to take behavioural changes into account when modelling realistic accessibility effects. Incorporating various (possible) behavioural changes may improve realism of computed accessibility effects. However, complexity increases as well.

As a result of pricing measures (with realistic charge levels) it is unlikely that a majority of all car trips will be subject to change (see summary/conclusions with regard to behavioural changes in section 8.2.2). It may therefore be worthwhile to focus specifically on the car drivers who do not change behaviour. These car drivers have to pay toll costs but as a result of the subgroup of car drivers who do change their driving behaviour they may benefit from travel time gains as well. If only travel time gains and pricing costs are taken into account, realistic accessibility changes can be computed in a relatively easy way for a majority of car drivers. For drivers who do change their behaviour this is different. Behavioural changes as a result of a charge are only made if the change in behaviour leads to a higher utility than when the trip change is not made. If the accessibility change for these car drivers were computed by not assuming a trip change (but by taking account of monetarized travel time gains and a charge component), an overestimation of accessibility loss (or an underestimation of accessibility gains) would be observed for these drivers. It is essential to realise that for these groups of drivers accessibility change in reality will be somewhat different and to determine at least the size and characteristics of the group of people for whom this overestimation of accessibility losses (or underestimation of accessibility gains) emerges. This can

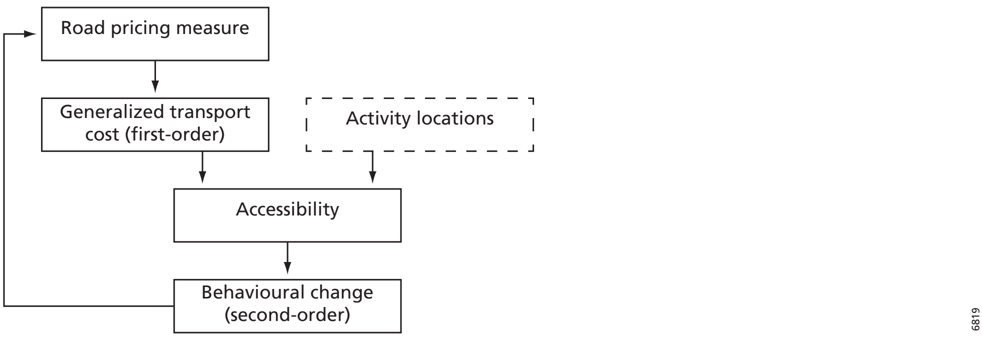

Figure 8.1: first and second-order effect of road pricing on accessibility.

be estimated on the basis of traffic simulation models or by using empirical data. Moreover, the aggregate loss in consumer surplus of the group of people who change their behaviour can quite easily be quantitatively estimated by using the economic 'rule-of-half'. This loss in surplus is equal to ½*(number of car trips changed)*(increase in generalized price) (see e.g. De Borger and Proost, 1997). The general price increase is equal to the charge level minus the financial benefits (e.g. as a result of travel time reductions).

In addition to short-term changes, relocations as a result of road pricing affect geographical accessibility on a longer-term. Trying to integrate these long-term effects rapidly increases the complexity of the modelling process: changes in activity locations first of all influence the location component of accessibility measures (i.e. the spatial configuration of activity locations) but changes in the location pattern cause network loads to change, resulting in changes in traffic resistance. Long-term effects can be determined by using land-use transport interaction models (LUTI) and/or empirical data.

What (kind of) behavioural effects are taken into account in modelling accessibility effects depends on the goal(s) of decision/policy-makers. In principle, behavioural changes can be incorporated in accessibility measures and the choice as to how detailed the process of modelling accessibility changes as a result of road pricing is made depends on a trade-off between complexity and realism of the results. Incorporating all possible behavioural effects as a result of road pricing makes the modelling task practically incomprehensible. In such situations utility-based measures may provide a solution, because in these measures all kinds of behavioural effects can in principle be incorporated. However, a disadvantage of utility-based indicators is that they do not measure 'actual' accessibility, but rather the valuation of accessibility (see section 2.5.2). Furthermore, aspects such as the interpretability are low and data requirements are high compared to more classical geographical accessibility measures. *Because, as indicated before, a majority of people will not change their driving behaviour and nor will they decide to relocate (see summary/conclusions of behavioural changes in section 8.2.2), modelling realistic accessibility effects (including travel time gains caused by others) for the large group of car drivers who do not change behaviour seems a relatively easy way to obtain a realistic insight into accessibility changes due to road pricing. The results can then be put into perspective by acknowledging that accessibility effects may be different for the small(er) group of car drivers who do change their behaviour. A quantification of their aggregate loss in consumer surplus can be estimated by means of an economic welfare approach (i.e. the 'rule of half').*

Revenue reinvestments and 'perceived' accessibility
As a result of road pricing measures revenues are collected. The government can reinvest these revenues in a number of ways (unless the price measure is not financed by the government). Some reinvestments (e.g. reducing fixed car taxes) may influence accessibility more strongly than other ones (e.g. using revenues for general means). In addition, the time scale within which revenues affect accessibility may vary. *Because reinvestments of revenues may influence accessibility changes as a result of road pricing either in the short-term or in the longer-term, ideally it would be sensible to incorporate these revenues when computing accessibility changes due to road pricing.* Nevertheless, especially some (short-term) revenues, which are reinvested in the transport system and can be incorporated in the generalized transport cost function, can be used practically in modelling accessibility effects. An example of such a rebate is the reduction of fixed car taxes. Other more spatially confined revenue reinvestments, such as reinvestments in infrastructure, which change

the configuration of the actual transport and/or land use system are harder to incorporate. A final important consideration in accessibility studies is the extent to which computed accessibility coincides with how accessibility is perceived by people. It is expected that the perceived (rather than the 'objective') accessibility is the key factor on the basis of which people make decisions to change behaviour. *Differences between perceived and more objective accessibility are, therefore, important to consider in accessibility studies in general. Nevertheless, in the case of road pricing, assessing these differences may even be more important because resistance to road pricing is high (Rienstra et al., 1999; Runhaar, 2001).* It is expected, therefore, that the difference between perceived and more objective accessibility may be greater than in other situations. The question as to how to take a sort of 'perception' component into account fell beyond the scope of this research.

Answering the first research question provided a theoretical insight into which type of accessibility measures can best be used to model the accessibility effects due to pricing and additionally shed light on the need to tailor the resistance function and the processes which have to be regarded when modelling accessibility effects due to road pricing. Moreover, this thesis aimed at obtaining greater insight into the sensitivity of accessibility outcomes to varying different road pricing cost and accessibility measure-related aspects. The sensitivity of accessibility outcomes we observed may have consequences for modelling the accessibility effects due to road pricing. The corresponding research question that was answered in chapter 4 is:

To what extent are geographical accessibility measure outcomes under road pricing conditions sensitive to varying cost (i.e. type of price measure, price level, specification of generalized transport cost function) and non-cost related aspects (i.e. accessibility measure, resistance parameter and network detail), and what implications for modelling geographical accessibility effects due to road pricing can be derived from these analyses?

Sensitivity to price measure, (in)elastic trip demand and charge level

The sensitivity of accessibility outcomes was studied by means of a job accessibility simulation study (in chapter 4, section 4.1 we provided the reasons for using a simulation approach and for looking specifically at job accessibility). Table 8.1 provides an overview of the variations we applied in the sensitivity analysis relative to a reference situation (see Table 4.1 in chapter 4 for

Table 8.1: summarized overview of the applied variations in the sensitivity analysis

Sensitivity analysis	Applied variations
Price measures	Time differentiated kilometre charge: • All roads • Roads with free flow speed ≥ 100 km/hour
Overall trip demand	Inelastic/elastic
Price level	6, 11 and 24 eurocent/kilometre during highest trip demand
Resistance parameter	Contour measure: cost equivalent 5, 10, 15 and 30 minutes Potential measure: power sensitivity parameter 0.5, 1, 2
Generalized transport cost function	Monetarized travel time and toll cost component: • VOT: 5, 11, 20 euro/hour
Network and zoning detail	Detailed network and zoning system: 2819 zones Less detailed network and zoning system: 441 zones

an overview of the reference situation). A more detailed insight into the sensitivity analysis we applied is provided in figure 4.1.

The sensitivity of accessibility effects to the price measure that was applied provided some insight into which types of measures lead to higher accessibility gains or lower accessibility losses compared to other measures. Within the analysis the sensitivity of outcomes was tested for two different price measures: a time-differentiated kilometre charge with the highest charge in the period with the highest traffic demand and a time-differentiated kilometre charge on roads with a maximum allowed free flow speed of 100 km/hour or higher. The charges amounted to € 0.11 per km in the highest demand period and € 0.034 per km outside that period. *Accessibility outcomes were found to be sensitive to the type of price measure.* As can be expected on the basis of the economic welfare theory, neither of the price measures lead to travel time gains, which on their own are high enough to compensate for the charging costs involved. Nevertheless, whereas the time-differentiated charge affecting all roads indicated a reduction in accessibility of around 60 percent (when only travel time and charging costs are considered) compared to the situation without pricing, the charge differentiated in time and space led to an accessibility decrease of around 4 percent. Traffic congestion in the study area occurred primarily on motorways. *In such situations where congestion only occurs at particular places in a road network, which is often the case in reality, a pricing measure that is differentiated in time and space may be more effective in reducing traffic congestion.* This merely confirms the already existing general view in literature (see, for example, May and Milne, 2000) that a more differentiated measure leads to stronger congestion reductions. The added value of this research was that the differences between the two pricing measures were assessed with a state-of-the-art traffic assignment model coping with detailed networks and blocking back effects. Moreover, not only travel time gains were analyzed but the influence of the (extra) costs as a result of pricing as well. A final added value is that differences in the spatial pattern of accessibility change as a result of both price measures could be compared (i.e. studying differences in where people benefit or suffer). This analysis showed that although spatial changes are different for both types of measures, similarities can also be found[180].

For both price measures accessibility effects were computed for assuming the overall trip demand to be elastic and inelastic. A cost-trip demand elasticity of -0.2 was applied for the elastic situation: a 10 percent increase in transport costs leads to a 2 percent decrease in the overall number of trips. In the case of the time-differentiated kilometre charge accessibility outcomes are insensitive to considering elastic or inelastic demand. The difference in accessibility decrease due to elastic demand is approximately one percent (i.e. 60 percent loss for inelastic and 59 percent loss for elastic demand). As can be expected, time gains on average do not compensate the charging costs even though time gains are higher when assuming elastic demand. For the spatially differentiated charge the sensitivity is higher because the charge is more in accordance to where congestion problems occur (i.e. the motorways). On other lower level roads where traffic congestion emerges less often no toll costs have to be paid. The accessibility decrease reduces from 8 to 4 percent as a result of elastic demand. The high sensitivity to the price measure and (in)elastic demand was also illuminated by the search for a trade-off value of time for which the same number of study area zones benefit and suffer from the pricing measures. For the time-differentiated kilometre

180 We found, for example, that, as a result of both measures, reductions in accessibility are lowest (and improvements highest) in and near highly populated regions where there are many job opportunities.

charge on all roads the trade-off values of time for considering respectively elastic and inelastic demand are approximately 250 and 1250 euro/hour. For the spatially differentiated charges this respectively amounts to approximately 20 and 100 euro/hour. *In modelling accessibility effects due to a particular road pricing it thus appears to be important to incorporate demand elasticity not only because it is quite unrealistic to assume inelastic demand due to road pricing but also because accessibility results are sensitive to demand elasticity.* The used elasticity value in the sensitivity analysis was -0.2. The observed sensitivity especially for the spatially differentiated measure implies that it is important to carefully assess (e.g. on the basis of literature) which elasticity factor should be used in modelling accessibility effects.

As a final specification of the price measure the influence of charge level was tested, but only for the kilometre charge raised on all roads (see section 4.1 for a motivation). Two other charge levels than the basic one were applied: € 0.06 and € 0.24 per kilometre (with respectively € 0.02 and € 0.08 per kilometre as corresponding charge levels outside the highest demand period). *The sensitivity to the charge level was found to be high.* Higher charge levels lead to higher travel times. As can be expected, travel time gains alone are not sufficient to compensate for the charging costs, even if travel time gains are higher as a result of a higher charge. In fact, the results are even opposite: higher reductions in accessibility were observed for the higher charge levels. The exact relationship between accessibility change and charge level is hard to determine without simulation due to different aspects that influence the sensitivity of accessibility outcomes such as the size of travel time gains, the charge level and the dispersion of activity locations (in this case jobs). The result of all these interacting processes is that a charge level that is made twice as high does not result in an accessibility change that is twice as high. In conclusion, the sensitivity analysis showed that results are sensitive to the charge level that is selected, and that it is hard to determine in advance which charge level leads to the most preferred accessibility effects. *It may therefore be wise to evaluate the effectiveness of a road pricing measure for different price levels before implementing the measure in the 'real world'.*

Sensitivity to VOT and for adding a fuel cost or revenue rebate component

Moreover, the sensitivity analysis studied the sensitivity of accessibility outcomes for the generalized cost function used. The valuation of time, which is used to translate travel time into financial terms, is an important component of the generalized transport cost function. A high sensitivity of accessibility outcomes for the VOT may imply that it is even more important to put an effort into differentiating the value of time towards different socio-economic/demographic groups than when the sensitivity is low. The sensitivity was tested for three values (see section 4.2.2. for the motivation of using these values): 5, 11 and 20 euro/hour. *The observed sensitivity to the VOT indicates that it is important to differentiate the VOT according to influencing socio-economic and/or demographic characteristics. A differentiation towards some important VOT-influencing factors, such as income, may already improve realism of accessibility outcomes substantially.* However, some preliminary stated preference research into people's perceptions of being better or worse off as a result of road pricing (used as proxy for perceived accessibility changes) indicated that these perceptions are rather insensitive to the size of travel time gains. This may suggest that *differentiation towards different values of time may be less important than incorporating perceptions in modelling accessibility effects.* Nevertheless, more research into the influence of perceptions is needed actually to be able to conclude that variation of the VOT is less important. Additionally, this thesis did not address how perception effects can be included when modelling accessibility effects due to road pricing.

Beside the sensitivity to the VOT, the influence of adding a fuel cost component or including a revenue use component (i.e. reducing or abolition of existing car taxation) was tested. Accessibility changes when adding a fuel cost component do not change a great deal. For contour measures accessibility changes are not influenced since a fuel cost was added in the situation with and without pricing. For the potential measure results do change a little due to the nature of the measure. *The question whether a fuel cost component should be included in modelling accessibility effects due to a pricing scheme does not really depend on the sensitivity of accessibility outcomes but merely on the question how people value fuel costs.* Do they value it in the same way (for example per kilometre) as a kilometre charge? This question was not answered in this thesis. When the decision is made to include fuel costs it may be good to differentiate fuel costs towards fuel type (e.g. diesel, gas, gasoline) and towards some 'car fuel consumption classes'. Yet, it remains questionable whether the extra effort that is needed to make that differentiation is worthwhile, considering the low sensitivity of accessibility outcomes to adding a fuel cost component. Subsequently, we tested the sensitivity to the revenue use component (i.e. reducing or abolition of existing car taxation). The type of sensitivity does not differ from that of changing charge levels. Depending on the goal of modelling accessibility effects and on the way revenues are reinvested, a revenue rebate component could be included.

Sensitivity to accessibility measure, accessibility parameter and network detail
The sensitivity of accessibility changes due to road pricing was studied not only for cost-related components (i.e. price measure and components in the generalized transport cost function), but also for the type of accessibility measure, the resistance parameter used and the level of zoning and network detail. Two types of accessibility indicators were used in the sensitivity analysis (in line with the observed suitability of accessibility indicators): contour and potential measures. Both measures in general give quite comparable results when the average accessibility increase/decrease for an average zone is regarded. Nevertheless, with respect to the spatial pattern of accessibility changes due to road pricing (i.e. where do the highest gains/losses occur) the sensitivity to the type of accessibility measure and additionally the sensitivity to either using absolute or relative accessibility changes is high. *This high 'spatial' sensitivity (i.e. sensitivity to where in the study area gains and losses occur) to the type of accessibility measure implies that either a motivated choice for using only one of the two accessibility measures should be made (although in effect this should always be done in every accessibility study) or that both accessibility measures are applied in order to put accessibility effects in a 'broader' perspective.*

An important methodological issue in all geographical accessibility studies is which type of resistance (sensitivity) parameter should be used in accessibility measures. The use of different resistance parameters may lead to quite different accessibility outcomes. The sensitivity of accessibility changes was tested for four cost impedance steps (cut off-values) in the case of contour measures (i.e. cost equivalent values of 5, 10, 15 and 30 minutes) and three cost sensitivity parameters (0.5, 1, 2) in the case of potential measures (see section 4.2.2 for the motivation of selecting each of the parameters). *The spatial sensitivity of accessibility changes due to road pricing (i.e. which zones benefit/suffer, and to what extent, as a result of road pricing) was found to be high. This implies that it is necessary either to make a carefully motivated decision with respect to the selection of* *the resistance factor (e.g. estimate the sensitivity factor for potential measures on empirical data) or to use more than one resistance parameter when a valid insight is required into the accessibility effects due to road pricing.*

A final point of consideration in the sensitivity analysis was the sensitivity to the level of zoning and network detail. Within this thesis two zoning levels and corresponding network systems were used. A relatively 'simple' network with 441 zones representing the origin and destination zones and the same study area with a more detailed network connecting around 2800 zones. *Results indicated that (in general) the sensitivity of accessibility changes to the level of network and zoning detail used is quite low.* A low sensitivity is thereby defined as small differences in the spatial pattern of accessibility change. A low sensitivity may imply that it is not essential to use a detailed zoning system when it saves substantial computing time. *Nevertheless, a more detailed network (and zoning system) is preferable from a realism point of view: the possibility of spatial differentiation of results is higher. Furthermore, when analyses are focused on a more disaggregate level (i.e. individual zones), (small) differences may be found.*

8.2.2 - Households: short-term and long-term behavioural effects as a result of transport pricing

This section provides an overview of short-term and long-term behavioural changes of households as a result of different pricing schemes. The corresponding research question, which was answered in chapters 5 (short-term changes) and 6 (long-term changes), is:

To what extent do (road) pricing policies influence short-term trip/travel patterns and (re)location, especially work and residential location, choices of households?

Section 8.2.2.1 answers the first part of the question regarding the short-term trip pattern effects. (Re)location results follow in section 8.2.2.2.

8.2.2.1 - Short-term behavioural changes

Change in car trips (commuting, social/visiting and other trips): frequencies

We analysed trip pattern changes of households as a result of pricing schemes for commuting, social (visiting) trips and one rest category classified as 'other trips' on the basis of a stated preference questionnaire held among 562 respondents. 288 of them were selected on the criteria of being a car commuter facing traffic congestion regularly. The other 274 respondents were selected on the basis of possessing a car in the household. Trip pattern changes were studied for three different kilometre charges: (i) a flat kilometre charge, (ii-a) a combined kilometre and time-differentiated peak charge or (ii-b) a kilometre charge differentiated with respect to car weight and (iii) a time dependent kilometre charge.

On average over all price measures (and price levels) respondents were found to be most likely to adjust current car trips for social (visiting) purposes (see Table 8.2). 11.6 percent of the total number of car trips made by all respondents is adjusted. For the category other purposes this amounts to 10.3 percent. The lowest car trip change intention was observed for commuting: 9.0 percent of the total car trips are changed. Although relative trip changes are the highest for social trips, this does not imply that the alterations in the traffic situation on aggregate are also the highest. Commuting and other trips are made more often. Together, all of the respondents indicated they make 3600 social trips by car on a four-week basis. For commuting and other trips the number of car trips is 6800 and 7800 respectively. Thus, *the lower relative changes in commuting or other trips will likely result in larger overall changes, because trips with commuting and other motives are made more often.* Moreover, average commuting trip distances are expected to be higher than average 'other' trip distances and are made more frequently during periods of high traffic demand. Therefore, commuting trip changes are expected to have the largest impact on the performance of the network (e.g. measured in average origin-destination travel time decreases during a day). Apart from questions about changes regarding the current car trips made, respondents were also asked whether or not they would make more car trips when a price measure would be implemented. This was only asked for commuting trips. *Approximately 0.5 percent more commuting trips will be made. Thus, for some respondents expected (monetarized) time gains probably exceed the charging costs making them decide to make more car trips than they currently do.*

Large differences in car trip changes were found for different price measures. *Time-differentiated price measures are particularly effective for changing commuting trips.* The commuting trip change percentages for time dependent charges (on average 13 percent) are more than a factor 2 higher than for price measures not differentiated in time (on average 5.0 percent). The highest change occurs as a result of a time-differentiated kilometre charge (14.8 percent). The lowest change was observed for a kilometre charge differentiated on the basis of car weight (4.0 percent). *Car commuters regard the option 'driving at other times', meaning the off-peak periods, as an interesting option probably because time changes may be relatively easy to make presumed that people are flexible in their starting times*. Changes in mode for example may have bigger implications. For trips made with a social (visiting) or with another purpose, time-differentiated charges still result in relatively high trip changes (12 percent on average for visiting; 11.2 percent on average for other trips). However, *the relative trip changes for social (visiting) or other purposes due to a time-differentiated charge are lower than for commuting. The measures, which are not differentiated in time, become more effective in comparison to commuting.* A flat kilometre charge is the second most effective measure for social (visiting) and other purposes when effectiveness is defined as the share of current car trips adjusted (14.2 percent visiting; 10.9 percent other trips adjusted).

Table 8.2: percentage of car trips changed due to pricing differentiated towards price measure and trip purpose

Percentage car trips adjusted	Time diff. km charge	Km charge + time depend. bottleneck toll	Flat km charge	Car weight depend. km charge	Cordon charge	Average all	Average time diff.	Average non-time diff.
Commute	14.8	11.2	5.9	4.0	no data	9.0	13.0	5.0
Social	14.6	9.1	14.2	8.4	no data	11.6	11.9	11.3
Other	13.2	9.2	10.9	7.9	no data	10.3	11.2	9.4
Daily shopping	12.7	no data	no data	no data	19.0	15.9	15.9	no data
Non-daily shopping	19.1	no data	no data	no data	24.3	21.7	21.7	no data

Overall, a time-differentiated kilometre charge remains most effective (14.6 percent of social trips changed; 13.2 percent other trips). For all trip purposes the kilometre charge differentiated on the basis of car weight is least effective (commuting: 4.0 percent; social (visiting): 8.4 percent; other: 7.9 percent). A possible explanation for the higher effectiveness of time-differentiated charges for commuting compared to social (visiting) or other trips may be that social (visiting) and other trips are already most often made in the weekends or in off-peak periods during working days. Time-differentiation is then less interesting/relevant for these kinds of trips. However, this may only partly be true since trip changes for a time-differentiated kilometre charge are still highest also for social (visiting) and other purpose trips. The higher intention of changing trips as a result of a flat (non-time-differentiated) kilometre charge for non-commuting trips, may have to do with a lower importance of social (visiting) and other trips. Commuting trips in general have to be made because people have to go to work. Social and other trips may be more discretionary.

Alternatives chosen for current car trips (commuting, social/visiting, other trips)
As described in the methodology section respondents had to divide the number of trips to be adjusted over different alternatives. These alternatives were (partly dependent on the type of charge): public transport, slow traffic, other motorized (own) traffic, carpool (only for commuting), travel at other times (for time-differentiated measures), work at home (commuting only) and no longer making the trip. Some regularities in the alternatives that are chosen for current car trips can be observed. *For the time-differentiated charges travelling at other times is the most interesting alternative.* Approximately 50 percent of the commuting car trips to be adjusted are made at another (cheaper) point in time. For visiting and other trips percentages amount to 45 and 43 percent averaged over the two time-differentiated charges. *In the case of commuting trips, public transport is the second most selected alternative when a time-differentiated charge is considered. In contrast, for social (visiting) and other trips slow traffic (walk, bike) was the second favourite option.*

For the pricing schemes that are not differentiated in time slow traffic is selected most frequently for all purposes (i.e. 32 percent of the to be adjusted trips in the case of commuting; 45 percent for visiting and 65 percent for other trips). Nevertheless, public transport is equally interesting as slow traffic for commuting trips. *The second favourite alternative in the case of trips with visiting or other purposes is not making the trip at all. For commuting, however, this is less interesting possibly because commuting trips are more constrained or are more important to make.* A general finding for all pricing schemes is that the popularity of the public transport option is rather stable over all measures (and trip purposes). Although not verified, there may be a fixed core of people who regard public transport as an interesting option independent of the type of charge. Another general finding for commuting trips is that working at home is not popular.

Change in car trips (daily and non-daily shopping): frequencies
Intended car trip changes with regard to non-daily shopping (e.g. luxury stuff) in another city and daily grocery shopping (not confined to a particular place) were studied on the basis of another survey (derived from a student course) among 266 respondents who use their car at least once a week for daily shopping and/or at least once a year for non-daily shopping in another city than where they reside. These shopping trip changes were examined for a time-differentiated kilometre charge and for a cordon charge around the four major cities in The Netherlands.

The average number of the total car trips that are intended to be changed amounts to 19 percent. This is higher than the 10 percent observed for trips with other purposes than visiting or commuting. The time-differentiated kilometre charge results for daily shopping seem to be in accordance with trip change results for visiting and other trips. However, *the high average percentage (i.e. 19 percent) is particularly caused by the cordon charge (see Table 8.2). This price measure was not taken into account for analyzing car trips for 'other' purposes.* For daily grocery shopping the respondents who were presented with the cordon charge had to imagine the daily grocery shopping to take place in one of the four major cities in the Netherlands (but a different city from where they reside): Amsterdam, Rotterdam, the Hague and Utrecht. These cities were chosen to make the cordon charge concrete and understandable. The choice for daily grocery shopping not to take place in the place of residence was made to be able to measure some effect of the cordon charge. In reality, however, daily grocery shopping in another city is quite uncommon when supermarkets are available where people live. For the time-differentiated kilometre charge respondents were asked to determine the influence of the charge on all daily shopping behaviour by car without any 'place restriction'. This (i.e. no place restrictions) may to a certain extent explain the large difference in the share of car trips that respondents intend to adjust as a result of the cordon charge (i.e. 19 percent of the shopping car trips) and the kilometre charge (i.e. 13 percent). The difference may also be (partly) due to characteristics of cordon charges in general. A cordon charge is a spatially differentiated charge (compared to the kilometre charges in this research). This spatial differentiation may result in a higher intention to try to divert the charge by adapting travel behaviour. Moreover cordon charges possibly cause a psychological boundary to pass the toll point: compared to a kilometre charge a relatively high toll has to be paid at one point in space.

With regard to non-daily (luxury) shopping, respondents had to indicate shopping car trip changes to another city as a consequence of a kilometre charge; the cordon charge remained to be tailored to non-daily shopping in one of the four major cities other than the place of residence. Again the cordon charge leads to higher car trip changes than the kilometre charge. *Comparing non-daily and daily-shopping trip changes the car trip change intention for non-daily shopping was found to be almost 1.5 times higher. Non-daily shopping trips are often more of a recreational nature and not directly needed for 'staying alive'. This may explain the higher intention of changing non-daily trips compared to the daily grocery trips.*

Alternatives chosen for current car trips (daily and non-daily shopping)
Respondents could choose to adapt their current shopping trips by car by choosing the following alternatives: public transport, other motorized own transport, travel at other times, combining trips, change shopping location and not making the shopping trip. *Popular alternatives for using the car for shopping trips are comparable to those observed for the trip purposes social (visiting) and the rest category 'other' trips (e.g. slow traffic for grocery shopping and public transport for non-daily shopping to another city). Also decreasing trip frequency is often chosen:* around 22 percent of the adjusted daily car trips are no longer made. For non-daily shopping this is even higher: approximately 35 percent. Only *travelling at other times does not seem to be really interesting.* We found that most respondents in the shopping questionnaire already make their shopping trips outside peak periods or in weekends. This gives a possible explanation for departure time changes being a less interesting option to decrease pricing costs. Finally, *a change in shopping location appears to be a popular alternative (more than 20 percent of the current car trips changed is diverted to*

another city) particularly for non-daily shopping in another city. The location change alternative was thereby formulated as 'doing shopping x-times per week more often by car closer to home' in the case of the kilometre charge and for the cordon charge as 'doing shopping an x number of times per year more often by car closer to home or in another city without a charge'.

Price levels and trip changes
In addition to differences in car trip changes due to the price measure or the trip purpose, the influence of the height of the charge and the type of revenue use was studied as well. This was done by using t-tests and ANOVA-analyses (see section 5.3.1 for a motivation) on the basis of the dataset with the three trip purposes (commuting, visiting and other trips) and 562 respondents. *There appears to be a general trend that respondents who have to pay higher charges intend to change more current car trips. However, the price effect is not as apparent as expected.* Price level influences are often significant (95 percent reliability) for the flat kilometre charge. Yet, almost no significant effects occur as a result of the kilometre charge differentiated on the basis of car weight. For the time-differentiated measures effects of price levels are also less significant compared to the flat kilometre charge and for the trips with social (visiting) and other trip purposes price height is not significant at all. Whenever possible 'price height' was defined in three ways: price level (charge/km), total annual toll cost (2 levels: higher/lower than mean or median toll cost) and total annual costs defined as toll costs minus revenues rebates (2 level: increase/decrease transport costs). All these cost aspects were presented to each respondent in the pricing scheme specification. *Statistical analyses showed that total annual toll costs and total annual costs were more explanatory for car trip change than the price level (e.g. charge/kilometre) itself.* A possible explanation for this finding is that total annual toll costs and total annual costs, which were presented in the specification of the price measure in the questionnaire, give greater insight to the respondent about actual consequences of the price measure (than the price level). Annual costs are more tailored to the specific situation of the respondent because it takes into account the kilometres driven by car and in the case of the annual cost the revenue rebates as well. Nevertheless, differences in trip change intentions due to different price heights are often not significant even in the case of annual (toll) costs. As a result of the shape of the dependent variables a sensitivity analysis was undertaken by using Tobit and Poisson regression analyses to study whether more significant price effects could be found (see section 5.3.1 for a more detailed motivation of using these techniques). This sensitivity analysis did not really lead to other insights.

In addition to the influence of price levels, the impact of the type of revenue use on trip change was studied too. *Merely two different types of revenue use were presented: 'reduction of income taxes' and 'reducing/abolition of fixed car taxes'. Lower (but not always significant) trip changes were observed for 'reducing/abolition of fixed car taxes'.* This may be caused by the specific traffic-related benefits due to reducing/abolition of fixed car taxes. On the other hand, it may also be explained by the explicit cost benefits that are presented to respondents in the questionnaire in the case of reducing/abolition of fixed car taxes whereas this was not done for 'reduction of income taxes'.

Characteristics explaining differences in car trip change as a result of pricing
In addition to the other analyses, the impact of socio-economic, demographic and trip related factors was studied. *Important explanatory factors for differences in intended car trip change behaviour are household income, travel cost compensation, the number of kilometres driven per year and the education level.* Households with higher incomes have a lower intention of changing car trips.

People receiving a total travel cost compensation indicated a significantly lower intention of changing car trips for all three trip motives and people who drive more car kilometres per year (annual kilometres driven equal to or larger than mean value of the sample i.e. 15,000 km) have a higher intention of changing car trips. The effect for education level is mixed. People with a high education level (high professional or university) indicate a significant higher intention of changing commuting trips or other trips but a lower intention of changing visit trips. More highly educated people may have more specialized jobs, which are not available everywhere. Therefore, people may have to follow the jobs, which may increase the distance to relatives. Moreover, people who have studied may have friends, which are scattered over a larger area. Alternatives for the car may thus be less interesting for social (visiting) trips over long(er) distances, especially when more family members participate in the social trip. For the exact influence of somewhat less explanatory variables such as age, gender and car weight see chapter 5, section 5.4.

8.2.2.2 - Long-term behavioural changes

The second part of the research question described at the beginning of section 8.2.2 (i.e. providing insight into observed household relocation intentions) was answered in chapter 6. Within this thesis two stages in the relocation process were distinguished: (i) the probability of relocating (jobs or residence) and (ii) the influence of trip (cost) and location related variables in the actual residential location choice. The job-related and residential relocation probability (i.e. first stage) was studied on the basis of a stated preference survey under 465 working respondents. Alongside studying relocation probabilities for the three kilometre charges described before, the influence of a cordon charge around medium sized cities on the relocation probability was assessed as well. The influence of trip (cost) and location related variables in the actual residential location choice (i.e. the second distinguished stage in the relocation process) was studied on the basis of a stated choice experiment held among 564 car commuters facing traffic congestion regularly. For details of the experiment see chapter 6, section 6.4.2. To analyse the relative importance of trip and location related variables multinomial (and mixed logit) models were estimated.

Probabilities to change residential and/or work location: stage 1 relocation process

On average (over all price measures and price levels) 5 percent of the respondents indicated a quite high, high or extremely high probability of moving to another residential location when a road pricing measure were to be implemented (see Table 8.3). The work relocation probability was found to be significantly (95 percent reliability) higher: on average about 13 percent of the respondents have a high job relocation probability. Thus, it would appear that respondents are more attached to their residential than to their work location. Moreover, a difference in relocation probabilities as a result of the type of price measures was found. *The cordon charge measure seems to lead to an on average higher relocation probability compared to a kilometre charge.* For residential relocation the difference is approximately 3 percent: around 7 percent due to the cordon and 4 percent as a result of the kilometre charges. The difference for job relocation amounts to 5 percent: approximately 16 percent for the cordon charge; 11 percent due to the kilometre charges. Differences in relocation probabilities as a result of the different kilometre charges are, however, small.

An important explanation for the higher relocation probability due to a cordon charge may be that it is easier to avoid (i.e. by relocating) cordon-related pricing costs compared to kilometre charging costs since cordon charges generally speaking are more spatially differentiated. It may, however, also be caused by a psychological threshold involved in passing a toll point: compared

Table 8.3: relocation probability due to pricing differentiated towards type of price measure

Relocation probability households due to pricing measures (percentage)	Kilometre charge (average)	Cordon charge	Average (all measures)
Residential relocation probability (quite-extremely high)	4.0	6.9	5.2
Job relocation probability (quite-extremely high)	10.7	16.3	12.9

to a kilometre charge, a relatively high toll price has to be paid at a particular location. Finally, the difference in probability may be (partly) occasioned by the respondent selection criteria determining whether or not a cordon charge was presented. Only respondents living and/or working in a medium sized city (minimum of 40,000 inhabitants), who are likely to cross a cordon, answered the cordon related questions. This may have led to an overestimation of the share of commuters considering relocation in comparison to the kilometre charge results (see also section 6.3).

The majority of respondents who indicated that there was a high probability they could relocate as a result of the road pricing measure already have a reasonably high chance of relocating within two years anyway. Additional analysis on the basis of relocation probabilities as a result of the kilometre charges showed that only 25 percent of the residential relocation responses due to road pricing originate from respondents who also indicated (in the same questionnaire) to have a (very) low probability of residential relocation within two years for whatever reason. The same result was found with regard to job relocation. *In conclusion, it would appear that especially respondents who already have a reasonably high probability of relocating within two years are likely to relocate as a result of road pricing.* The observed relocation probabilities do not imply that every respondent who indicated to have a reasonably high probability of changing will actually relocate when a road pricing measure is implemented. Stated preference researches may lead to an overestimation or underestimation of actual relocation probabilities, possibly because respondents cannot imagine the actual consequences and/or because certain respondents want to make a point because they are particularly opposed to or in favour of pricing. Moreover, some people who indicated they would not relocate may actually relocate as a result of road pricing in reality.

Characteristics explaining differences in relocation probabilities due to pricing
To gain insight into explanatory socio-economic, demographic and trip related variables that may explain differences in relocation probabilities due to pricing, ordered probit models were estimated. At first sight it may seem strange to try to do an analysis into explanatory factors given the relatively low share of respondents who have a high relocation probability. However, from a methodological point of view it is possible because all 465 respondents indicated their relocation probability on a 7-point categorical scale. Nevertheless, although the applied approach is defendable from a statistical point of view, estimation results will be based particularly on (differences between) the primarily filled low probability classes. *Important influencing factors are: income, annual number of kilometres driven, partial or total travel cost compensation, education level and probability of relocating within 2 years for whatever reason.* Households with a higher income have a lower probability of relocating due to pricing. People who drive more car kilometres per year (more than 19,000 km) have a higher relocation intention as do persons who do not receive travel cost compensation. People with a higher education are less intended to relocate. Finally,

people who already have a high intention of relocating for whatever reason indicated there was also a higher probability they would change their residential and/or work-related location specifically as a result of (road) pricing measures.

The outcome of the ordered probit analyses reported in chapter 6 showed that *many observed explanatory variables for relocating due to pricing are in accordance with explanatory factors for relocation as found in general relocation studies.* The most important difference is that factors such as income and travel cost compensation seem to play a more important explanatory role in the relocation probability as a result of road pricing. And in contrast to other relocation studies (without considering road pricing) where people with higher incomes often indicate to have a higher relocation intention (see, for example, Van Wee, 1994), people with higher incomes seem to have a lower relocation intention as a result of a (road) pricing scheme. Furthermore, *differences between explanatory factors for work and residential relocation were analyzed. These differences in general were found to be small. The same goes for differences in explanatory factors for kilometre and cordon charges.* Finally, the influence of price levels was tested. *Price level or price measure differences (except for relocation probability differences between the cordon and the kilometre charges) did not have a significant influence on relocation probability.* The number of kilometres driven has a higher explanatory power, causing the price variable to become insignificant. Price levels thus seem to have a lower influence on long-term (relocation) behaviour than on short-term car trip behaviour. However, the influence of price levels has not been studied as extensively for long-term as for short-term trip pattern changes.

Influence trip and location variables in residential location choice: stage 2 relocation process
Travel cost (i.e. toll and fuel) appeared to be an important factor in the residential location decision of households. *First of all, respondents are more sensitive to travel costs than to equally high (monthly) housing costs. Secondly, travel time appears to play a less important role as indicated by a low value of time of around 3 euro/hour.* This is almost 4 times lower than the average VOT estimated on the basis of a short-term (combined route, departure time) choice experiment among practically the same type of respondents. It would appear that when location factors are included the influence of travel time in the total preference trade-off of households decreases. *Overall the conclusion is that respondents in general prefer to pay somewhat higher housing costs and accept longer travel times in order to avoid (high) travel costs.* Another observation was that toll costs are valued a bit more negatively than fuel costs, leading to a lower VOT for toll costs. Nevertheless, these differences are small. Not only travel cost is an important factor. *Location-related factors, such as the type of location and the number of bedrooms, seem to be important components in a residential location choice as well.* Finally, from an analysis into explanatory characteristics there are two strong effects that emerge. *Respondents with a higher income seem to value travel costs less negatively, leading to a higher value of time, and individuals with a longer current trip time are less sensitive to both travel time and travel costs.* The VOT of individuals with a longer commuting trip is lower, which can be interpreted as a self-selection effect: those placing a lower value on travel time are likely to travel longer (commuting) distances.

Some considerations regarding the relocation results can be made. The relocation probabilities were shown to be considerably high for 3-16 percent of the respondents (dependent on the type of charge). *The size of the percentage of respondents who intend to change the residential location specifically due to the pricing scheme (i.e. a low probability of relocating anyway) may not be strange considering* *the costs that are involved with relocating*. Transaction costs for buying a house in the Netherlands are approximately 12 percent of the value of the house (Van Ommeren and Leuvensteijn, 2003). Transaction costs consist of transfer costs (around 6 percent), notary costs and real estate-agent costs (Van Ommeren and Leuvensteijn, 2003). Given the average purchase price of a house in the Netherlands of approximately 230,000 euro (RTLZ, July 2006), this means that the transaction costs involved in buying a new house on average amount to almost € 28,000. These costs do not include possible costs for furnishing the new house, although periodically these furnishing costs also emerge when one does not relocate. When it is assumed that a flat kilometre charge of € 0.06 per kilometre is introduced (this is the average charge level for the flat kilometre charge applied in this thesis) and an average car driver drives 17,000 kilometres per year (Autotrack.nl, 2000), this would imply that a car driver has to pay around € 1,000 per year extra for toll costs. Moreover, when drivers partly benefit from revenue investments, the actual costs are lower than € 1,000. These figures indicate that, on average, a car driver can drive for around 30 years without adjusting his/her behaviour (trip pattern and locations) before the transaction costs are traded-off. From this point of view it seems to make little sense for homeowners to relocate as a result of a pricing scheme if they do not intend to do so anyway. For people who rent the situation is different. They do not have to pay transaction costs for moving. *Analyses into explanatory factors indeed showed that homeowners indicated a significant lower relocation probability as a result of pricing.* Attempts to transfer the results of this section to other countries must be made with a degree of caution, because the transaction costs of relocating are likely to be different from those in the Netherlands. Van Ommeren and Van Leuvensteijn (2003) reported transaction cost differences (in percentage of the property value) between six European countries in 1999. Transaction costs for Germany, Denmark and the UK are lower than in the Netherlands. In France and, especially, Belgium these costs are higher.

Within the questionnaire the implicit assumption was made that house prices do not change as a consequence of the introduction of a pricing scheme. In reality a new market equilibrium in house prices might occur because of changing demands: some locations may become more, others less interesting. Furthermore, possibly increasing costs of living as a result of transport pricing may cause housing prices to decrease in general. All these possible price changes may affect relocation probabilities on the long-term. Another point of consideration is that due to budget and questionnaire time limitations the influence of travel time gains or reliability gains on the relocation probability could not be studied. If travel time gains would have been included in the questionnaire, observed relocation probabilities may have been different. For some respondents lower relocation probabilities may have been found because of the travel time benefits. Higher probabilities than observed may occur as well. Time gains may cause 'more preferred' residential and/or work location to come within people's reach, leading to relocation. However, the first effect (i.e. lower relocation probabilities) as a result of time gains seems more likely to occur.

8.2.3 - Firms: road pricing, accessibility and short-term and long-term behavioural effects

The final question that was answered in chapter 7 is:

To what extent does (road) pricing influence the perceived accessibility and short and long-term behaviour of firms?

To answer the research question a stated preference research was carried out among 485 firms in the industrial and business service sectors. Firms were asked to indicate perceived changes in accessibility and intended behavioural adjustments in the short (i.e. trip pattern, employee compensations or services, product prices) and long-term (i.e. relocations) as a result of a time-differentiated kilometre charge. The kilometre charge was specified in the same way as in the household questionnaire. Revenues were used to lower income taxes.

Perceived accessibility change firms
Accessibility was defined as the 'effort' it takes to reach another location (for example customers, the consumer market) by car from the settlement location as well as the 'effort' it takes to reach the settlement location by car (for example for employees, customers or suppliers). The 'effort' can depend on all kinds of aspects, such as travel time, reliability of travel time and travel costs. Respondents had to indicate their expected change in accessibility due to the charge on an ordinal scale with 7 classes. Four related questions were asked. In the first question no explicit formulations of possible travel time and reliability gains were provided. The other three questions assumed benefits in the form of an improvement of the travel time reliability, and a 25 percent and 50 percent decrease in delay time respectively.

In case no benefits were given, 14 percent expected a decrease in accessibility (see Table 8.4); 8 percent expected an increase and a majority of 78 percent expected no change. When travel benefits were incorporated in the question a larger group with perceived accessibility gains was observed. A non-defined improvement of the travel time reliability resulted in the following accessibility change expectations: 7 percent decrease, 24 percent increase and 69 percent no change. Specification of travel time gains resulted in around 40 percent of the respondents expecting an accessibility improvement compared to 50 to 55 percent that expected no change. *Thus, it would appear that the perceived accessibility change of firms as a result of the kilometre charge to a degree depends on whether or not guarantees can be given regarding improvements in the current travel time and/or reliability of travel time.* In addition to these results, ordered probit analyses were conducted to gain insight into firm characteristics explaining differences in the perceived accessibility change. *Firms employing 50 or more employees and firms that perceive their settlement to score relatively better (than other firms) on several settlement location cost, employee cost and trip cost related aspects also indicated a relatively higher improvement (or lower decrease) in accessibility due to the charge. On the other hand, businesses in the industrial sector, firms working mainly on a municipal scale with respect to customers/sales and firms that score relatively better on branch location and accessibility-related aspects showed a relatively lower improvement (or higher decrease) in perceived*

Table 8.4: perceived accessibility changes due to kilometre charge differentiated towards benefit assumption

Changes in accessibility by car from and to the settlement location due to the km charge (percentage of firms)	**Accessibility gets worse**	**Accessibility gets better**	**No change**
No additional assumptions	14.2	7.6	78.1
Improvement reliability of travel time	7.4	23.7	68.9
Decrease of travel time in congestion (25 %)	5.0	39.2	55.9
Decrease of travel time in congestion (50 %)	4.6	42.9	52.6

accessibility as a result of the kilometre charge. For further explanations of the observed relations see chapter 7, section 7.3.

Short-term behavioural changes firms

Within the questionnaire trip pattern changes were studied for two types of trips: changes in business and transportation of goods trips. For each trip purpose respondents were asked to answer two questions: the change in car/lorry trips in general and the change in the trips made inside/outside the peak period. Answers had to be given on a categorical scale with 7 classes ranging from making far fewer to far more trips. *Around 19 percent of the respondents indicated to make fewer car/lorry trips for business traffic due to the kilometre charge and only 3 to 4 percent of the firms intended to make more trips (see Table 8.5).* Most firms do not expect to change business trips (78 percent). Changes in the period of driving (i.e. avoiding the high charge peak hours) seem more likely to be made than choices to reduce the overall frequency of travelling by car/lorry. Approximately 40 percent of the firms pointed out to make more trips outside the peak. *Trip alterations for transportation of goods were found to be lower probably because transportation of goods is of a more vital importance for the existence of firms that undertake such trips or because trips for transportation of goods are less easy adjustable. 6 percent (compared to 19 percent for business trips) of the firms intend to make fewer trips for transportation of goods, against 3 to 4 percent that indicated to make*

Table 8.5: intended behavioural changes due to kilometre charge

Behavioural changes firms	**Less often (percentage of firms)**	**More often (percentage of firms)**	**No change (percentage of firms)**
Short-term			
Trips by car in general			
Business trips	18.8	3.5	77.6
Transportation trips	6.1	3.4	90.5
Trips by car outside peak			
Business trips	4.1	39.7	56.0
Transportation trips	1.9	27.5	70.2
ICT as substitute for current car trips			
Commute trips	2.2	35.0	62.9
Business trips	2.1	35.1	62.8
Other short-term changes	*Percentage of firms*		
Increase product/services prices			
Likely	50.7		
Unlikely	25.9		
Not unlikely/likely	23.3		
Employee policy changes			
Km or fuel cost compensation	18.8	11.5	69.7
Offering business car	19.8	5.1	75.1
Public transport cost compensation	8.9	18.7	72.4
Residential relocation compensation	10.5	16.7	64.1
Flexibility in choosing working times	6.6	29.3	64.1
Flexibility in working at home	3.9	30.7	65.4
Long-term changes	*Probability*		
Relocation probability (quite-extremely high)	7.8		

more. Timing-related changes seem to be interesting: approximately 28 percent of the firms will undertake trips for transportation of goods more often outside the higher charged peak periods. *Whereas the reported trip pattern alterations are substantial, most firms that point out they intend to adapt their current trips pattern indicate they will only do so to a limited extent.*

Other short-term changes were examined as well, but only on a quite superficial level: the use of ICT as substitute for current trips and the likeliness of changing product/service prices as a result of the kilometre charge. The use of ICT appears to be a promising alternative to save extra costs for business or commuting traffic due to pricing. Furthermore, a reasonably large share of the firms tries to mitigate (extra) costs due to pricing by increasing prices (i.e. approximately 50 percent).

Changes in employee compensations/services offered by firms were also analyzed on a categorical scale. *Around 30 percent of the firms pointed out to change something regarding the employee compensations.* Car cost related compensations such as fuel cost reimbursements or the offering of a business car seem to be provided less often as a result of the kilometre charge. Almost one-fifth of the firms intend to provide these types of cost compensations less often. Public transport or relocation grants may be given more often (i.e. on average about 18 percent of the firms). *However, for employers it seems most interesting to mitigate the commuting costs of employees by offering them a higher flexibility in choosing their working hours and by allowing them to work at home more often:* approximately 30 percent of the firms expect they will offer these flexibilities more often.

Long-term behavioural changes firms and influencing characteristics

Finally, relocation effects were studied. *Eight percent of the firms pointed out that it is likely that their firm will relocate as a result of the kilometre charge (see Table 8.5). Roughly half of these firms already had a (quite) high probability of relocating within 2 years.* Ordered probit analyses provided insight into which type of firms are more or less likely to relocate as a result of the road pricing measure. Firms that consist of more than one settlement location, firms that perceive a reduction in the attractiveness of their location as a consequence of pricing and businesses that expect a decrease in the accessibility of employees indicated a relatively higher relocation probability as a result of the kilometre charge. On the other hand, a relatively lower relocation probability was observed for firms that score relatively better than other firms on building characteristics and accessibility, on the flexibility of rules and contacts and score higher on expansion and parking space. Moreover, more locally and regionally oriented firms with respect to sales, firms that are located in the north and east of the Netherlands and firms with more than 100 employees also seem to have a lower inclination to relocate as a result of a kilometre charge. Finally, no strong relationship between short-term behavioural changes, such as intended employee compensations and/or trip pattern changes, and long tem relocations was found. Further explanations of the observed directions of relations/effects can be found in chapter 7, section 7.5 and 7.6.

8.3 - Conclusions

In this section, the conclusions of our research are presented. Section 8.3.1 begins by presenting the overall conclusions. More specific conclusions (for each topic) are presented in section 8.3.2 to 8.3.4. Section 8.3.2 focuses on specific accessibility-related conclusions. Subsequently, sections

8.3.3 and 8.3.4 elaborate on conclusions regarding the behavioural effects of households and firms respectively.

8.3.1 - Overall conclusions

The following three overall conclusions can be formulated on the basis of this study:

- This study has shown that it is possible to determine accessibility effects due to road pricing in a relatively easy way with tailored geographical accessibility measures. However, the effects are sensitive to how accessibility is computed.
- People intend to adjust their behaviour when a road pricing measure is introduced. As can be expected more people intend to make changes in their car trip behaviour than in their residential and job locations. However, relocation effects do seem to occur, and they are not negligible.
- As is the case with households, more firms intend to change their trip behaviour than their settlement location due to road pricing. Again, settlement relocations are certainly not negligible.

8.3.2 - Accessibility-related conclusions

- Contour and potential accessibility measures are well-suited measures to compute accessibility effects due to road pricing.

There are various types of geographical accessibility measures. On the basis of a multi-criteria analysis contour and potential accessibility measures emerged to be well-suited measures to compute realistic geographical accessibility effects due to road pricing against relatively low cost/effort. These accessibility measures consist of an activity location (i.e. opportunity) component on the one hand and a resistance function on the other hand. A generalized transport cost function approach can be used in which a conventional resistance component such as travel time is translated into financial terms by multiplication with a value of time. An extra cost component as a result of road pricing can then be added. The influence of road pricing on the generalized transport cost function can be seen as a first-order effect.

- To model 'realistic' accessibility effects due to road pricing, it makes good sense to differentiate the generalized transport cost function of accessibility measures towards (value of time) influencing factors.

From a theoretical point of view it is important to differentiate the generalized transport cost function because (groups of) people with different characteristics value travel time savings in a different way and thus may be affected differently by road pricing measures. Additionally, sensitivity analyses in which values of time were systematically varied in computing accessibility effects due to/as a result of pricing pointed out that accessibility outcomes are sensitive to VOT variations. Both the increased realism when differentiating the generalized transport cost function as well as the sensitivity of accessibility outcomes for the size of the value of time used indicate the usefulness of differentiating the generalized transport cost function towards different values of time. Income differentiation may already improve the realism of accessibility effects substantially.

- From a practical point of view it is wise to model realistic accessibility effects for the large group of people who (almost) do not intend to change their car trip behaviour as a result of road pricing. The size of the welfare losses of people who do change their behaviour may be easily determined by using the economic rule of half.

As a result of road pricing measures, people may change their behaviour on the short (e.g. changes in the trip pattern) and longer-term (e.g. location changes). Behavioural changes can be seen as secondary effects. These secondary effects in turn influence the accessibility. In order to model realistic accessibility effects the influence of behavioural changes should be regarded. Still, the far majority of current car trips will not be changed due to road pricing (i.e. more than 85 percent of the current car trips). Making a trade-off between the effort it costs to model all behavioural effects (if that is possible at all) and the extra gain that would give in realism of accessibility outcomes, it may be most worthwhile to aim at modelling realistic accessibility effects for the group of people who do not change behaviour. To derive realistic accessibility effects for this group, benefits must be incorporated. An important benefit component is the travel time gain caused by the people who do change their behaviour. The influence of the behavioural changes on network travel times can be assessed by using a traffic assignment model. When applying this procedure for people who in fact do change behaviour (i.e. assuming no change in behaviour but take into account charging costs and travel time gains), accessibility decreases are overestimated (or increases underestimated) for them. This should at least be addressed when reporting results. A relatively easy way to get an aggregate quantitative approximation of welfare losses of these people who change behaviour is to make use of the economic 'rule of half'.

- Computed accessibility changes due to road pricing are sensitive to varying the type of price measure and the charge level.

A charge, which is differentiated in space and time, leads to higher travel time gains and a lower reduction in accessibility (or higher increase) than the same (time-differentiated) charge, which is charged on all roads. This confirms the general expectation that a more differentiated charge is more effective in reducing congestion problems. As can be expected on the basis of economic welfare theory, on average travel time gains alone did not compensate for the extra charging costs neither for the spatially differentiated nor for the kilometre charge on all roads.

Moreover, the influence of varying price levels (i.e. eurocent/kilometre) was assessed. Accessibility outcomes are sensitive to the height of the charge. Results indicated that a higher charge does not have to lead to higher accessibility gains (or lower accessibility losses) due to road pricing. In fact the opposite was found for the kilometre charge on all roads: higher charge levels lead to higher accessibility decreases than lower ones.

- Computed accessibility changes are sensitive to the type of accessibility measure used in the analysis. This may imply that it is good to use the potential as well as the contour measure to get a thorough insight into accessibility effects due to road pricing measures.

This sensitivity to the type of accessibility measure is especially due to differences in how various accessibility measures work (see e.g. sections 2.4 and 2.5). A contour measure for example uses a chosen resistance step and determines which opportunities can be reached from a certain origin location within that resistance. A potential measure on the other hand, does not work with a fixed impedance. Instead a more gradual resistance (decay) function is used. Such differences influence the results. Since the sensitivity of accessibility for the type of measure is high, one must know particularly well what one wants to know or express by using a particular accessibility measure. If this is not the case it is probably better to use several indicators in order to be able to give a sort of 'bandwidth' of accessibility effects.

8.3.3 - Conclusions regarding the behavioural reactions of households

Changes in the car trip pattern of households

- The highest changes in current car trips as a result of pricing measures occur for shopping trips, respectively followed by social, other (i.e. other than social and commuting) and commuting trips.

Changes in shopping-related car trips were studied on the basis of another dataset than car trip changes for the social, commuting and other trip purposes. The observed higher changes in car trip behaviour for shopping purposes is especially due to the fact that a cordon charge was (in addition to a time-differentiated kilometre charge) included in the 'shopping related' survey whereas respondents were not confronted with a cordon charge in the survey for the other three trip motives. A cordon charge seems to lead to a higher trip change intention. Possibilities to avoid a cordon charge compared to a non-spatial-differentiated kilometre charge may be higher leading to a higher trip change intention. Additionally a cordon charge, where a toll has to be paid at one point in space, may lead to a higher psychological boundary to pass it.

Since commuting trips (i) occur relatively frequently, (ii) on average are likely to have a higher length than trips for social, other and shopping purposes and (iii) are made more often in periods of high traffic demand, commuting trip changes probably have the highest influence on travel times in areas that currently have to cope with traffic congestion delays.

- The most effective road pricing measure for changing current car trips of households is a time-differentiated kilometre charge, at least compared to three other (kilometre based) price measures (i.e. a flat charge plus an extra time-differentiated bottleneck charge, a flat kilometre charge and a kilometre charge differentiated according to car weight).

For commuting and social trips almost 15 percent of the current car trips are adjusted. For other trips around 13 percent of the trips are changed. The (low) flat kilometre charge plus an extra time-differentiated bottleneck charge is the second most effective (with respect to car trip change) charge for commuting trip change: 11 percent of the car trips are adjusted. For social (visit) and other trips a flat charge is more effective: respectively 14 and 11 percent of the current car trips are changed. For all trip purposes the kilometre charge differentiated on the basis of car weight is least effective (commuting: 4.0 percent; social (visiting): 8.4 percent; other: 7.9 percent). Around 0.5 percent of the respondents indicated to make more commuting car trips when a pricing measure would be introduced (average over all measures). These respondents might expect travel time benefits. And for them these time gains seem to compensate the (higher) charging costs.

- The type of pricing measure largely influences the alternatives chosen for current car trips.

  - Time-differentiated (kilometre) charges: a change in the period of driving is the most often chosen alternative for current car trips.
  - Non-time-differentiated charges: public transport (only for commuting) and slow modes (walking, cycling) are chosen most often. For social and other purposes slow modes are preferred far more often than public transport.

- Reducing car trips (i.e. demand decreases) due to road pricing is chosen regularly only for non-commuting purpose trips.

In general it may be harder to change commuting trips compared to other kinds of trips. Many people for example do not have the opportunity to work (more) at home or to choose more flexible working hours (e.g. work longer on certain days and compensate these hours by taking other days off).

- In the case of shopping trips that are currently made in another city by car, shopping at other locations closer to home is a viable option (20-25 percent of the current shopping trips by car to another city are relocated).

Relocations of households

- The probability that households will search for another job (closer to home) due to road pricing is on average higher than the probability they will change their residential location (i.e. move closer to work).

Apart from changes in the trip pattern, relocation probabilities were studied too. Around 4 percent of the households have (quite) a high probability of changing their residential location and approximately 11 percent to change their job location as a result of a kilometre charge.

- A cordon charge around medium sized and large cities leads to higher relocation probabilities compared to differentiated kilometre charges which are not differentiated in space.

For a cordon charge higher relocation percentages were found compared to the kilometre charges: between 3 to 5 percent more respondents have a high relocation probability.

- Especially households who have a high probability of relocating anyway within two years (thus without road pricing) on average also indicated to have a higher relocation probability specifically as a result of road pricing.

75 percent of the (high) residential relocation responses due to road pricing originate from respondents who also indicated to have a (very) high probability of residential relocation within 2 years for whatever reason. Thus it seems that road pricing can form the trigger to relocate especially for people who already have an intention of changing house and/or work location.

- Car drivers are sensitive to travel costs (i.e. fuel and toll costs) in the case of choosing a location where to reside.

Respondents were found to be more sensitive to changes in travel costs than to equally high changes in housing costs. Further, respondents attach a relatively low importance to travel time as indicated by low value of time estimates. *Overall this may lead to the conclusion that respondents in general prefer to pay somewhat higher housing costs and accept longer travel times in order to avoid (high) travel costs.*

Explanatory variables for behavioural changes as a result of road pricing

- Charge level does not seem to have a strong impact on behavioural changes. Although higher charge levels regularly seem to lead to higher current car trip changes, the results are often statistically insignificant.

For relocation probabilities no significant influence of price level was found (at all). This may however be partly caused by the influence of price level not being examined so thoroughly as for short-term changes.

- Important statistically significant socio-economic/demographic and trip related explanatory variables (both for short-term and long-term changes) are income, travel cost compensation and the annual distance driven by car.

Respondents with a higher income and respondents receiving travel cost compensation intend to adjust fewer current car trips and have a lower probability of changing location than respondents with a lower income and/or without getting cost compensation. In contrast, respondents who drive more than an average amount of kilometres per year have a higher probability of changing behaviour due to pricing. Additionally, the relation between trip and location behaviours was statistically tested. It was found that respondents who intend to change their car trip behaviour as a result of pricing also have a higher probability of relocating due to pricing. It thus would appear that there are 'cost-sensitive' households that try to mitigate pricing costs in several possible ways. Nevertheless, this finding may be somewhat counterintuitive and it needs further research.

8.3.4 - Conclusions regarding the firm (behavioural) reactions

- Firms on average considerably value benefits due to pricing.

If travel time benefits or increases in the reliability of travel time are explicitly given, the perceived accessibility change of firms as a result of a time-differentiated kilometre charge on average is slightly positive. Without those explicit gains firms on average expect a slight accessibility decrease.

- Business trip changes due to road pricing are more likely to be made than changes in trips for transportation of goods.

20 percent of the firms indicated to make fewer car/lorry trips for business traffic; 6 percent of the firms intend to make fewer trips with regard to the transportation of goods. The transportation of goods is probably more vital to the existence of firms that are engaged in transporting goods, or there may be less room for change. Not all firms however intend to make fewer trips: 3 to 4 percent of the firms indicated to make more (business or transportation of goods) trips when the

kilometre charge would be introduced. These firms probably expect to benefit from travel time or travel time reliability gains.

- Firms on average intend to compensate employees less often for car related costs when road pricing is introduced; other compensations and flexibilities are offered more often.

Around 30 percent of the firms intend to make one or more changes regarding compensations. Car cost-related compensations (fuel cost, business/company car are) will be provided less often. Public transport or relocation grants on average are given more often (about 18 percent of firms). The most frequently selected option is allowing employees greater flexibility in choosing their working times and in working at home: approximately 30 percent of the firms intends to offer this more often.

- As was found for households, firms that indicated to have a high relocation probability specifically as a result of road pricing often are those firms that have a high probability of relocating within two years anyway (thus without road pricing).

Around 8 percent of the firms indicated a (quite) high probability of relocating. Half of these firms already have a (quite) high relocation probability within 2 years.

8.4 - Policy recommendations

Recommendations can be given following from both research lines within this thesis: (i) modelling geographical accessibility effects due to road pricing and (ii) assessing behavioural effects as a result of pricing schemes. With respect to modelling geographical accessibility effects this section gives the most important recommendations of which many already were implicitly described when answering research questions 1 and 2 in section 8.2.1.

- If the aim is to assess effects of road pricing from a combined transport and spatial view it may be advisable to use geographical accessibility indicators instead of or in addition to using economic (e.g. welfare analysis) or transport indicators (travel time changes).

The advantage of using geographical accessibility measures is that the measures give detailed insight into which parts of a study area (e.g. regions, zones) benefit/suffer to what extent from certain (road) pricing measures. Studying these 'spatial' implications and differences may be particularly worthwhile when effects of spatially differentiated charges have to be examined. This thesis showed for example that the spatial pattern of accessibility changes (i.e. which regions/ zones benefit or suffer) is sensitive to the (spatial) differentiation of pricing measures.

- On the basis of this thesis it is recommended to use contour or potential accessibility measures with a generalized transport cost resistance function to model accessibility effects as a result of road pricing.

Making some differentiation in the generalized transport cost function of accessibility measures is advisable. This can be done by differentiating values of time used for monetarizing travel time towards some important influencing factors. At least a differentiation towards income classes is recommendable since income is an important VOT-influencing factor.

- Because the majority of car drivers do not intend to change their driving behaviour as a result of pricing it is recommended to focus on modelling realistic accessibility changes for this group of car drivers.

However, in interpreting modelled accessibility effects it is advisable to at least acknowledge that the applied procedure overestimates accessibility decreases (or underestimates increases) for those people who change behaviour. Insight into the types of people who primarily change behaviour can be derived from for example a stated preference research as conducted in this thesis. An estimation of the total loss in consumer surplus of these people can be approximated by using economic welfare analysis (i.e. the rule of half).

On the basis of the second line of research, in which behavioural effects due to pricing schemes were assessed, some recommendations can be given with regard to effective pricing schemes.

- If the policy goal is to reduce traffic congestion, a time-differentiated kilometre charge (higher charge peak, lower charge off-peak) seems to be more effective than a flat charge. Additionally, an in time and space differentiated kilometre charge may be even more applicable for reducing travel times.

Traffic congestion in many countries often occurs on highways. If motorways are tolled more highly in the case of a spatially differentiated charge, a part of the traffic will divert to the secondary network. Whether this is preferable/acceptable depends on what decision makers want. The finding that more spatially differentiated measures are more effective in reducing congestion problems is not a new shocking observation. It merely confirms the expectation (see, for example, also May and Milne, 2000).

Time-differentiated measures are effective for changing commuting trips by car. It derives this effectiveness especially from departure time changes. A flat kilometre charge on the other hand, is almost as effective in changing current car trips for visiting and other trips. And maybe more important it reaches this effect by letting people choose other alternatives than the car. From this point of view a flat kilometre charge might have more environmental friendly effects than a time-differentiated charge. The final selection of a pricing scheme will not only be dependent on its behavioural implications but for example also on the acceptability of the measures among people. This acceptability issue was not studied in this thesis.

- If effectiveness of a pricing measure (i.e. defined as the number of current car trips changed) is the primary goal of policy-makers it is advisable to use revenues for lowering income taxes. If acceptance of a pricing measure is important, it may be better to use revenues to abolish existing car taxation.

Pricing measures lead to revenues. Policy-makers (or others) may reinvest these revenues in different ways. Within this research the influences of two types of revenue use were studied: (i) reducing income taxes and (ii) abolition of existing car taxation (purchase and ownership). For the first type of revenue use (lowering income taxes) higher behavioural changes of households were observed possibly leading to a stronger reduction in travel times in congestion sensitive areas. Using revenues for traffic-related investments (e.g. abolition existing car taxation) on the other hand, leads to lower traffic changes but the revenue itself may be more acceptable (see Ubbels, 2006). The type of revenue use to be preferred depends on assessments decision makers make.

- From an effectiveness point of view it may not be advisable to compensate 'sensitive' groups of people by reducing their car related costs again.

Income proved to be an important explanatory factor for observed differences in behavioural change. People with lower incomes indicated to make more changes in their current trip pattern and in their locations. It has not been studied to what extent people with lower incomes 'suffer' in a monetary sense from pricing schemes. Yet, if these income groups loose much it may from a social equity point of view be considered to compensate these groups with money derived from the pricing schemes. It is then recommendable not to let money flow back again into the transport system in such a way that the incentives to change car behaviour are weakened. It may be better to compensate 'sensitive' groups in another manner such that preferred effects of the charge are not faded away.

- To increase the effectiveness of road pricing measures policy-makers may try to influence firms to provide non-car cost related compensations/services to employees even more often.

It was observed that people who receive a travel cost compensation from their employer are less intended to change their current car trip pattern or their locations. Firms indicated to intend to compensate employees more often in a different way, such as providing public transport and relocation grants and/or offering employees the ability to work (more) at home. These different types of compensations and or services might increase peoples' intentions to change their car behaviour.

- If the success of a pricing measure is based on the effectiveness of a particular charge it is recommended to also take location effects into consideration.

Relocation effects may be important to take into consideration in evaluating the effectiveness (e.g. in the form of traffic congestion relief) of transport pricing measures. Relocation probabilities may look low (compared to trip changes) but can have considerable impacts on the congestion level. Relocations are likely to lead to shorter commuting distances possibly leading to lower congestion levels at certain locations and time points. Shorter distances may additionally result in mode changes (e.g. more often slow traffic) for several trip purposes. This in turn may improve traffic conditions by car.

Car commuters were also shown to be sensitive to travel costs. This may imply that although many people do not consider a relocation due to pricing, they take travel costs into account when choosing a location where to reside. Eventually many people change locations during their life. The influence of travel costs may then result into more efficient travel patterns (for example shorter distances) in the longer-term. Because on average toll costs seem to be important, the traffic congestion reduction on a longer-term may even be larger (as a result of shorter travel distances in the case of a kilometre charge).

8.5 - Directions for further research

This section provides some directions for further research. Section 8.5.1 offers suggestions for further research, which will enlarge the insight into accessibility and the sensitivity of accessibility effects due to road pricing. Section 8.5.2 gives points for improving the measurement of and thus the insight into behavioural effects of households and firms as a result of road pricing. Whereas these first two subsections offer further research suggestions that are fairly practical and form small improvements/extensions to the measurement of effects in this thesis, section 8.5.3 provides more extensive lines for new (partly different) research.

8.5.1 - Further research to extend the insight into (the sensitivity of) accessibility

- In further research it may be good to study (the sensitivity of) accessibility effects for other types of pricing measures too. From a geographical point of view, cordon charges (located around cities) are interesting.

The accessibility modelling study primarily focused on giving directions with regard to how to model accessibility effects due to road pricing measures. Within the accessibility simulation study the sensitivity of accessibility outcomes was assessed for two kilometre charges: a time-differentiated kilometre charge and a kilometre charge differentiated in time and space. Because of their relative simplicity cordon charges are popular measures to reduce traffic (congestion) related problems in cities. The resulting accessibility effects (including the sensitivity) due to a cordon charge may be rather different compared to kilometre charges since the measures are (more) spatially differentiated and less gradual (i.e. compared to kilometre charges one has to pay a relatively high toll at one point in space).

- Insight into (local) accessibility effects due to road pricing measures might be enhanced by studying effects for other types of study areas as well.

The sensitivity of accessibility outcomes due to road pricing was studied on the basis of the 'Eindhoven' study area. Although the sensitivity of accessibility outcomes (i.e. average accessibility changes in the study area) are expected to be rather robust for the type of study area, the disaggregate local effects may be different for other study areas. Within the study areas used, Eindhoven, the largest city in the study area, dominated the spatial effects as a result of the large number of zones and jobs available within the city. Moreover, although traffic congestion emerges within the study area, congestion problems in the Eindhoven region are not as severe as in parts of the Dutch Randstad area. From a geographical point of view (i.e. what locations are influenced and to what extent by road pricing) it might be interesting to study accessibility effects (and the sensitivity of these effects) also for other types of study areas, e.g. study areas with more severe congestion problems, study areas where there is not one 'dominating' city.

- Further research should also study discrepancies between perceived and more objectively 'computed' accessibility more thoroughly.

Perceived accessibility is important because it is expected that people decide to change their behaviour on the basis of perceived accessibility rather than on the basis of objective accessibility (i.e. computed with combinations of toll costs and travel time gains). Therefore, it is important to close a potential 'gap' between objectively computed and perceived accessibility as much as possible. The results presented in Appendix D provided some indication that perceptions may play a larger role than travel time gains in the way people see accessibility. However, we did not analyse what the perception of certain types of people is. With this information the resistance function of accessibility measures might be adjusted. How this should be done is a matter of future research. In addition, further research into people's perceptions of accessibility may benefit from a more thorough use of psychological theories e.g. including concepts of attitude and decision making theories.

8.5.2 - Directions for improving the measurement of behavioural changes of actors

- Further research should shed more light on the influence of price height on behavioural effects by making intra-personal price height assessments possible.

The height of toll costs did not prove to be a strong explanatory factor for the observed differences in behavioural change. This is not in accordance with what one might expect. Several possible reasons for the relatively low sensitivity to price levels were given in chapter 5. An important cause may be the type of data. Due to budget reasons, only one price level variant per type of price measure was shown to each respondent. This means that intra-personal influences of price levels (per price measure) on behavioural changes could not be studied. This may in part explain the low explanatory power of price height. Additionally, it may have been hard for respondents to actually 'feel' or imagine the toll costs while only seeing them on paper (or in this case on a computer screen), even though scenarios were adapted to the respondents personal situation (i.e. total toll and travel costs per year were presented on the basis of the current travel pattern). Since price level is an essential component in constructing a price measure, it is important to gain greater insight into price (height) effects. This insight may be derived from using other types of experiments in which people, for example, have to spend/distribute a certain budget of (real) money among different trip alternatives. It is at least advisable to study behavioural changes by showing one person different price levels, such that intra-personal influences of price levels can be studied.

- Additional research should give greater insight into the influence of travel time gains on behavioural changes of households and firms for example by systematically varying such benefits in stated preference surveys.

Within the description of price measures, on the basis of which respondents (households and firms) had to indicate intended behavioural changes, no scenarios for possible travel time gains were shown. This was not possible due to budget limitations and differences of interest in the consortium. If travel time gains would have been stated, observed behavioural changes may have been different. Appendix D and section 7.3 combined for example gave some (possible) indication that, to state it freely, commuters attach a lower value to travel time benefits (caused by pricing) than firms do. However, additional research is needed to be able to draw more firm conclusions on the influence of travel time gains.

In stated preference surveys it is difficult to give people a reliable indication as to how high the travel time gains will be. One way to avoid the difficulty of using exact and realistic travel time gains, while still allowing researchers to study the influence of travel time gains on behavioural changes, is to include different travel time gain 'levels' into the experiment, and subsequently to present respondents one or more scenarios with (different) travel time gains. It is advisable to retain one variant without time gains as a reference situation.

8.5.3 - Lines for more extensive further research

- It would be interesting to focus more on studying actual spatial consequences of road pricing measures. This can also be done by means of stated preference surveys.

Although some insight was gained into the probability of people choosing a residential location closer to work and/or a work location closer to home, the thesis provided almost no insight into the actual spatial consequences. Questions such as to what extent certain types of people reduce or even increase their distances (i.e. commuting and other) could not be answered on the basis of the data. Moreover, as far as firms are concerned we only studied the relocation probability, but no information was gathered as to where individual firms locate. Are they going to locate nearer to specific other firms (i.e. forming clusters), are they changing regions (for example going back to the western part of The Netherlands because traffic congestion decreases as a result of pricing), etc.? We simply did not have the budget or time required to examine such spatial aspects.

- In addition to studying behavioural effects at an individual household or firm level it is worthwhile to examine macro-implications of all individual changes. This can probably be done best by using simulation models.

The implications of short-term trip changes for network travel times and level of services can be investigated by using traffic simulation models as done in this thesis for accessibility modelling. Longer-term implications, such as which (type of) regions get more or less attractive to locate, can be studied by using land use transport interaction models. At the same time these models can also estimate to what extent land use changes in turn affect the level-of-service on road networks.

- It may be worthwhile to study the interdependencies between changes in household and firm behaviour due to road pricing more explicitly. A possible way to do this is by conducting interviews or surveys among firms as well as their employees, in such a way that behaviour of employers and employees can be linked.

Behavioural changes of households and firms as a result of pricing measures may not be independent of each other. Firms can compensate employees for travel related costs and location decisions of firms may influence the residential location of households. On the other hand, (certain) employees may have some power in demanding certain compensations from their employer and employee relocations may in the end impact firm locations. These interactions cannot be studied directly on the basis of the current datasets. However, through deduction, the possible importance of the mutual interdependency of households and firms can be explored on the basis of the results of this thesis. These results provided some indication that firms intend to offer compensations for kilometre or fuel costs less often when road pricing is introduced. People currently receiving travel cost compensation indicated a relatively lower inclination to change trips or locations. An important consideration now is whether or not people currently receiving such compensations expect to be (partly) compensated for the additional costs involved when a (road) pricing measure is introduced. If households expect to be compensated without actually being compensated, this may have a bigger impact on their behaviour than what we observed on the basis of the household questionnaires. Although firms indicated they intended to offer car cost-related compensations less often, they want to offer compensation for public transport and relocation more frequently. This may make individual car trip changes to public transport and relocation probabilities higher than observed on the basis of the questionnaires. Moreover, firms want to offer (certain) employees a higher flexibility in working times and in the choice whether or not they want to work at home. Short-term trip changes are likely to be influenced by these offered flexibilities as well. Since the interdependencies between firm and households seem to be important and could not be studied thoroughly on the basis of the available data, doing further research into these interdependencies is important.

- To derive a more thorough image of the impact of pricing schemes on activity locations chosen would be interesting. This insight may be derived by doing another stated preference study.

With respect to household relocations, this thesis focused specifically on residential and work-related relocations. People are, however, likely to also engage in other activities (e.g. shopping, recreating etc.) which are scattered in space. Pricing schemes may influence the locations chosen for several of these activities. This thesis provided only some insight into activity location changes for shopping trips.

- It may be interesting to look beyond the effect road pricing measures may have with regard to specific trip purposes exclusively, and to put the individual and his surrounding (possibly at different points in time) more central and to look at the consequences pricing schemes might have for the individuals' daily activity pattern. A possible way to study this is by conducting activity time budget diaries in a stated preference setting.

In this study we examined all the behavioural changes separately and independently from one another. Trip pattern changes, for example, were examined with a focus on the individual trip purposes. In reality, everything a person does during a day is interconnected. Because people work during the day, for example, most leisure activities take place in the evenings or at weekends. The interdependency between different activities can be studied by means of activity time budget diaries in a stated preference setting. One may first ask respondents to fill in their activity pattern during a day (i.e. departure times, arrival times, transport mode, type of activity, duration time etcetera). Afterwards interviewers can ask respondents to indicate changes in their activity pattern as a result of the introduction of a pricing scheme.

- As a final point being mentioned here, it may be interesting to study how households and firms react on different price measures that aim at achieving certain location goals.

In this research the focus with respect to location effects was primarily put on studying location effects for road pricing measures, which particularly aim at variabilising fixed transport cost and reducing traffic congestion. However road pricing could also be used as a policy measure to reach certain location goals such as clustering of firms or pushing firms or households to spread to less congestion sensitive regions.

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Appendix A - An overview of the contents and the division of tasks in the MD-PIT project

Four Dutch universities took part in the MD-PIT (a Multi-Disciplinary study of Pricing policies In Transport) project: Free University Amsterdam (VU), Groningen University (RUG), Delft University of Technology and Utrecht University (UU). As can be seen in Table A1 the project was divided into mono-disciplinary and multi-disciplinary sub-studies. The mono-disciplinary sub-studies were carried out within each institute separately. Their topics are provided in Table A1. In the multi-disciplinary studies the participants from the various universities worked together. In total, five multi-disciplinary study topics were conducted, each supervised by one institute, as indicated by the black square. In addition, each university was involved in one or more other sub-studies supervised by one of the other participants.

One of the main elements of the multi-disciplinary study was a combined empirical questionnaire research. Within the questionnaire research all the participants included the questions and experiments they needed to answer their specific research questions. The overall coordination of the total MD-PIT project was in the hands of the Free University in Amsterdam. The coordination of the empirical questionnaire research was carried out by Groningen University (RUG). More details about the project, including publications, can be found on the project's website: http://www.feweb.vu.nl/md-pit.

Table A1: contents of the total project and the division of tasks over the four participating universities

	Economic perspective Free University Amsterdam (VU)	Geographical perspective Utrecht University (UU)	Psychological perspective Groningen University (RUG)	Traffic engineering perspective Delft University of Technology (TUD)
		Monodisciplinary sub-studies		
	The economics of transport pricing:	*The geography of transport pricing:*	*The psychology of transport pricing:*	*Transport pricing in dynamic traffic network models:*
	a literature review	a literature review	a literature review	a literature review
	Institutional economic aspects of transport pricing (public versus private operators; different spatial scale levels of organization)	Transport pricing, congestion impacts, generalized transport costs and implications for accessibility measures	'Motivation crowding out' in transport pricing: substitution and complementarity between pricing, self-control and other behavioural strategies	The simultaneous modelling of route and departure time choice in the presence of dynamic road pricing
		Multidisciplinary sub-studies		
1 Behavioural responses to transport pricing (mobility, modality, route, timing; habits and uncertainty)	•		o	o
2 Transport network pricing, accessibility, siting perception and locational behaviour (households, firms)	o	•	o	
3 Transport pricing, revenue use, public perception and social acceptability	o		•	
4 Pricing in dynamic transport networks	o			•
5 Transport pricing technologies, real-time information provision, and dynamic spatial and traffic network effects		o		•
	Overall coordination		Coordination questionnaires 'households' and 'firms'	

• Sub-study leadership; o Sub-study involvement
Source: the MD-PIT website (www.feweb.vu.nl/md-pit)

Appendix B - Description of question variables and response scales in the empirical research

This section describes in detail the characteristics of the questionnaires: the questions/variables and the responses that could be given. The original questionnaires were in Dutch. This section only provides a short description of the variables (freely translated from Dutch). For a total overview of the Dutch questionnaires, one can approach the author. The outline of this section is as follows. Tables B1 en B2 describe the characteristics of household questionnaires 1A en 1B, respectively. In addition, table B3 provides insight into household questionnaire 2. Tables B4 and B5, finally, present the details of household questionnaire 3 and the firm questionnaire. A further description/explanation of the fieldwork can be found in chapter 3. It must be noted that the presented following order of the variables in this section is not always exactly in line with how things were presented in the questionnaires.

Tabel B1 Household questionnaire 1A: short-term trip trade-offs (stated choice)

Questions/Variables	Response categories/scales
• GENERAL (PERSONAL) QUESTIONS	• GENERAL (PERSONAL) QUESTIONS
Gender	male; female
Age	… years old
Highest attended education level (either finished or not)	LO-LBO; MAVO; MBO; HAVO-VWO; HBO, university bachelor; university masters
Highest finished education (diploma)	LO-LBO; MAVO; MBO; HAVO-VWO; HBO, university bachelor; university masters
Province of the Netherlands where respondent lives	1 out of the 12 provinces could be selected
Number of inhabitants in municipality	< 10,000; 10,000-20,000; 20,000-50,000; 50,000-100,000; 100,000-400,000; > 400,000
Region (of residence) within The Netherlands	3 biggest cities in the West (Amsterdam, Rotterdam, The Hague); rest West; North; East; South
Number of working hours per week	> 40; 40; 35-39; 30-34; 25-29; 20-24; 15-19; <15; don't know/don't want to say; not employed
Status partner	self-employed; employed in public sector, other paid employment; no work; don't know/don't want to say
Income (household gross annual)	27 classes; don't know; don't want to say
Income (household gross annual): 4 classes	< 28,500; 28,500-45,000; 45,000-68,000; > 68,000 euro; don't know; don't want to say
Household size	1; 2; 3; 4; 5; 6+
Number of adults in household	1; 2; 3+
Number of children in household	0; 1; 2; 3; 4+
Number of children in household (age 0-11)	0; 1; 2; 3; 4+
Household composition	single; single + children; partner, no children; partner + children
Renter/owner of the house	renter; owner
Zip code home address	…

Questions/Variables	Response categories/scales
• ACCEPTABILITY OF PRICING MEASURES	• ACCEPTABILITY OF PRICING MEASURES
Respondents were presented with three different price measures. For a detailed overview of these measures (i.e. bottleneck passage, kilometre charge differentiated by vehicle type, kilometre charge with different charge levels and different revenue use) including the different characteristics, see Table 9.1 in Ubbels (2006). After seeing each price measure respondents were asked questions regarding:	
Justness/righteousness of the price measure	7-point Likert scale (very unjust – very just)
Likeliness of reducing (own) car kilometres due to measure	7-point Likert scale (very likely – very unlikely)
Perceived likeliness of a decrease in congestion problems due to measure	7-point Likert scale (very likely – very unlikely)
Perceived likeliness of a decrease in environmental problems due to measure	7-point Likert scale (very likely – very unlikely)
Expectation of in general being better or worse off due to the measure	7-point Likert scale (probably far better- probably far worse off)
Expectation that the price measure can be implemented without problems with current technologies available	7-point Likert scale (totally agree – totally disagree)
Perceived acceptability of the price measure	7-point Likert scale (very acceptable – very unacceptable)
Probably I buy a more environmental friendly car (only asked in case of a kilometre charge differentiated to vehicle type)	7-point Likert scale (totally agree – totally disagree)
• PRIVACY PROPOSITION	• PRIVACY PROPOSITION
Perception that by introducing an electronic device that registers the car kilometres privacy is affected	7-point Likert scale (totally agree – totally disagree)
• REVENUE USE PERCEPTIONS	• REVENUE USE PERCEPTIONS
Revenues go to the government treasury without a specific destination	7-point Likert scale (very acceptable – very unacceptable)
Revenues are used to construct new roads	*idem*
Revenues are used to improve the quality of the public transport	*idem*
Revenues are used to abolish the current car usage taxes (MRB)	*idem*
Revenues are used to reduce fuel taxes	*idem*
Revenues are used to reduce income taxes	*idem*
• PERCEPTION OF BETTER/WORSE OFF	• PERCEPTION OF BETTER/WORSE OFF

Questions/Variables	Response categories/scales
Respondents were shown two different kilometre charge measures with different charging cost and travel time gain combinations (for details see Appendix D). Respondents were asked to indicate whether they thought they would be better off or worse off due to each price measure.	7-point Likert scale (probably far better- probably far worse off)
• OPINION QUESTIONS	•OPINION QUESTIONS
I think of car driving as:	I think of car driving as: 7-point Likert scale (much fun – no fun at all) 7-point Likert scale (very good – very bad) 7-point Likert scale (very pleasant – very unpleasant) 7-point Likert scale (very positive – very negative)
If I have to go somewhere I automatically take the car	7-point Likert scale (totally agree – totally disagree)
I do not have alternatives for the car	*idem*
I often choose the car as transport mode without consciously thinking about it	*idem*
It would take effort not to drive the car anymore	*idem*
If I use my car often I feel morally aggrieved	*idem*
Driving the car is part of my routine	*idem*
I can reduce my car use easily	*idem*
I do not feel morally obliged to use more environmental friendly transport modes such as the bike or public transport	*idem*
I often choose the car as transport mode without realising it in advance	*idem*
Even if I use the car less often I'm still well capable of doing my daily things	*idem*
Driving the car is typical for me	*idem*
It is against my principles to use the car if well-suited alternatives are available	*idem*
• STATED CHOICE (LOCATION)	• STATED CHOICE (LOCATION)
Needed input questions for the choice experiment regarding:	
Type of house	detached; semi-detached; house in a row; apartment
Rent or owner-occupied house	rent; owned
Monthly housing costs	…. euro
Stated choice experiment (9 choice screens per respondent), see section 3.4.3 for details.	

Table B2 Household questionnaire 1B: opinions and long-term (location) trade-offs

Questions/Variables	Response categories/scales
• GENERAL (PERSONAL) QUESTIONS	• GENERAL (PERSONAL) QUESTIONS
Gender	male; female
Age	… years old
Highest attended education level (either finished or not)	LO-LBO; MAVO; MBO; HAVO-VWO; HBO, university bachelor; university masters
Highest finished education (diploma)	LO-LBO; MAVO; MBO; HAVO-VWO; HBO, university bachelor; university masters
Province of the Netherlands where respondent lives	1 out of the 12 provinces could be selected
Number of inhabitants in municipality	< 10,000; 10,000-20,000; 20,000-50,000; 50,000-100,000; 100,000-400,000; > 400,000
Region (of residence) within The Netherlands	3 biggest cities in the West (Amsterdam, Rotterdam, The Hague); rest West; North; East; South
Number of working hours per week	> 40; 40; 35-39; 30-34; 25-29; 20-24; 15-19; <15; don't know/don't want to say; not employed
Status partner	self-employed; employed in public sector, other paid employment; no work; don't know/don't want to say
Income (household gross annual)	27 classes; don't know; don't want to say
Income (household gross annual): 4 classes	< 28,500; 28,500-45,000; 45,000-68,000 euro; > 68,000; don't know; don't want to say
Household size	1; 2; 3; 4; 5; 6+
Number of adults in household	1; 2; 3+
Number of children in household	0; 1; 2; 3; 4+
Number of children in household (age 0-11)	0; 1; 2; 3; 4+
Household composition	single; single + children; partner, no children; partner + children
Renter/owner of the house	renter; owner
Zip code home address	…
Zip code work address	…
Frequency of constraints cost by tight activity schedule	
Car constraints	5-point Likert scale ((almost) always – (almost) never)
Departure time constraints	5-point Likert scale ((almost) always – (almost) never)
Chance of moving house (within 2 years)	5-point Likert scale (very small – very big)
Chance of changing job (location) (within 2 years)	5-point Likert scale (very small – very big)
Possibility to work at home	yes always; yes … days/month; no
Number of days per month actually working at home	…
• INPUT QUESTIONS STATED CHOICE EXP.	• INPUT QUESTIONS STATED CHOICE EXP.
Days per week with car to work	on average …. times per week
Days per week in traffic jam (in the morning)	on average …. times per week
Commuting distance by car (one-way)	…. km
Preferred departure time	(hour, minute)
Always the same route to work	yes; no
If no, travel time other route (compared to regular one)	on average the same length (in time); longer (…. min.); shorter (…. min)
Actual departure time (normal situation)	(hour, minute)

Questions/Variables	Response categories/scales
Arrival time (in general)	(hour, minute)
Arrival time constraint at work	yes (+ exact indication); no
Departure time constraint at home	yes (+ exact indication); no
Transport options available for commuting trip	carpool; train; bus, tram, underground; bike, foot; no alternative
Average commuting travel time with public transport	…. min
Payment of commute-related transport costs *If, (partly) compensated than respondents were additionally asked to give a separate indication of compensation per type of compensation*	self; partly compensated by employer; totally compensated
Type of fuel car used most regularly	gasoline; diesel; LPG
Weight class car	light; medium-weight; heavy
Total amount of annually driven kilometres by car	…. km
• STATED CHOICE POINT EXPERIMENT	• STATED CHOICE POINT EXPERIMENT
Stated choice (4 choice screens per respondent), see section 3.4.2 for details.	*Stated choice (4 choice screens per respondent), see section 3.4.2 for details.*
•EXPLORATION RELOCATION PROBABILITY	•EXPLORATION RELOCATION PROBABILITY
In this part of the questionnaire a kilometre charge was introduced with an unrealistically high charge level (€ 0.30/kilometre) to explore (maximum) relocation probabilities that could be expected. Moreover, the sensitivity of relocation responses was studied by dividing the respondents over two groups and asking different questions per group. This information was used to construct better (more valid) relocation related questions in household questionnaire 2.	
Group A:	
Chance of moving closer to work due to the charge	5-point Likert scale (very small – very big)
Reasons for not changing (in case of very small, small chance)	accept extra costs and just pay; expect compensation from employer; use car less often to go to work/use other means
Group B:	
Options one considers in the case of the implementation of the kilometre charge (more than one answer categories could be selected)	accept extra costs and just pay; expect compensation from employer; work more at home; change residence (closer to work); mitigate costs through using the car less often to go to work/use other means; economise on other expenses; other reaction

Table B3 Household questionnaire 2: short-term and long-term behavioural changes

Questions/Variables	Response categories/scales
• GENERAL (PERSONAL) QUESTIONS	• GENERAL (PERSONAL) QUESTIONS
Gender	male; female
Age	… years old
Highest attended education level (either finished or not)	LO-LBO; MAVO; MBO; HAVO-VWO; HBO, university bachelor; university masters
Highest finished education (diploma)	LO-LBO; MAVO; MBO; HAVO-VWO; HBO, university bachelor; university masters
Province of the Netherlands where respondent lives	1 out of the 12 provinces could be selected
Number of inhabitants in municipality	< 10,000; 10,000-20,000; 20,000-50,000; 50,000-100,000; 100,000-400,000; > 400,000
Region (of residence) within The Netherlands	3 biggest cities in the West (Amsterdam, Rotterdam, The Hague); rest West; North; East; South
Number of working hours per week	> 40; 40; 35-39; 30-34; 25-29; 20-24; 15-19; <15; don't know/don't want to say; not employed
Status partner	self-employed; employed in public sector, other paid employment; no work; don't know/don't want to say
Income (household gross annual)	27 classes; don't know; don't want to say
Income (household gross annual): 4 classes	< 28,500; 28,500-45,000; 45,000-68,000; > 68,000 euro; don't know; don't want to say
Household size	1; 2; 3; 4; 5; 6+
Number of adults in household	1; 2; 3+
Number of children in household	0; 1; 2; 3; 4+
Number of children in household (age 0-11)	0; 1; 2; 3; 4+
Household composition	single; single + children; partner, no children; partner + children
Renter/owner of the house	renter; owner
Zip code home address	…
Number of cars available in household	… cars
Type of fuel of car used normally	gasoline; diesel; LPG (gas)
Weight class car	≤ 1000 kg; 1000-1250 kg; > 1250 kg
Avg. annual car kilometres (of respondent)	… kilometres
Division of annual kilometres over trip purposes	commute; social/visit; other
Avg. annual car kilom. (of resp.) in car used in general	… kilometres
Avg. number of times usage of car in 4-week period to:	
Go to work alone	… times
To carpool	… times
To visit someone	… times
To do other things	… times
Paid job	yes; no
Zip-code work address	yes, …; don't know; don't want to say
Distance home work by car ('normal' route)	… kilometres
Possibility to work at home	yes always; yes … days/month; no
Fixed times to arrive at work	yes; no
Payment of costs related to commuting trips	pay yourself; partly; totally compensated by employer

Questions/Variables	Response categories/scales
Type of costs compensated by employer	*(visible on request)*
Number of times/week with car in traffic jam	average … times per week
Satisfaction with the current 'home situation'	7-point Likert scale (very satisfied – very dissatisfied)
Satisfaction with the current 'work situation'	7-point Likert scale (very satisfied – very dissatisfied)
Chance of moving within 2 years	5-point Likert scale (very small – very big)
Chance of changing job within 2 years	5-point Likert scale (very small – very big)
• PRICE MEASURES 1 TO 3	• PRICE MEASURES 1 TO 3
Introduction price measure 1 (flat kilometre charge)	
Perceived likeliness that:	
Congestion problems decrease due to measure	7-point Likert scale (very unlikely – very likely)
Environmental problems decrease due to measure	7-point Likert scale (very unlikely – very likely)
Questions regarding intended changes in current car trips for: commuting purposes, social visiting purposes, other purposes	*(visible on request)*
Likeliness (due to the charge):	
To change the residential location (closer to work)	7-point Likert scale (very unlikely – very likely)
To search for another job (closer to home)	*idem*
To sell the (or on of the) car(s)	*idem*
Perceived righteousness/justice of the price measure	7-point Likert scale (very just – very unjust)
Perception of in general being better off or worse off due to the price measure	7-point Likert scale (probably far better- probably far worse off)
Perceived acceptability of the price measure	7-point Likert scale (very acceptable – very unacceptable)
Introduction price measure 2A (flat km charge + time dependent bottleneck charge)	
Same questions as under price measure 1	
Introduction price measure 2B (car weight dependent kilometre charge)	
Same questions as under price measure 1	
Introduction price measure 3 (time dependent kilometre charge)	
Same questions as under price measure 1	
• PRICE MEASURE 4: cordon charge	• PRICE MEASURE 4: cordon charge
Live and work in same city/town	yes; no
Work within the built-up area	yes; no
Leave the 'official' built-up area from home to work	yes; no (dependent on previous answers)
Live in a medium/big town (min. 40,000 inhabitants)	yes; no (dependent on previous answers)

Questions/Variables	Response categories/scales
Drive through other medium/big towns from home to work	yes, … towns; no (dependent on previous answers)
Introduction price measure 4 (cordon charge around cities with a minimum of 40,000 inhabitants)	
Perceived acceptability of the cordon charge	7-point Likert scale (very acceptable – very unacceptable)
Likeliness (due to the charge):	
To change the residential location (closer to work)	7-point Likert scale (very unlikely – very likely)
To search for another job (closer to home)	7-point Likert scale (very unlikely – very likely)
• PROPOSITIONS	• PROPOSITIONS
Price measures are just/righteous if:	
The price is the same for everyone	7-point Likert scale (totally disagree – totally agree)
I personally do not loose too much	*idem*
People who contribute to the problems (e.g. congestion, environment) to a large extent have to pay more	*idem*
The low income groups can keep using their car when needed	*idem*
I am not harmed more than others	*idem*
The revenues are used to the benefit of car drivers	*idem*
I think of car driving as:	I think of car driving as: 7-point Likert scale (much fun – no fun at all) 7-point Likert scale (very good – very bad) 7-point Likert scale (very pleasant – very unpleasant)
Propositions regarding car driving:	
If I have to go somewhere I automatically take the car	7-point Likert scale (totally disagree – totally agree)
It would take effort not to drive the car anymore	*idem*
I regard the national government as reliable	*idem*
I feel morally obliged to not use the car in case of suitable alternatives being available	*idem*
People who are important for me think I should use the car less often	*idem*
Most people I know use the car regularly	*idem*
Car use affects the liveability in cities due to noise and smell nuisance	*idem*
Driving the car is part of my routine	*idem*
Even if I use the car less often I'm still well capable of doing my daily things	*idem*
Car use takes a lot of space causing the remaining space for cyclists, pedestrians and children to decrease	*idem*
Most people in my environment think I should use the car less often	*idem*

Questions/Variables	Response categories/scales
Car use is an important cause for traffic unsafety	*idem*
I can not make a contribution to solutions for problems caused by car use	*idem*
I have faith in the national government keeping their promises	*idem*
It is a habit in my surroundings to use to go everywhere by car	*idem*
I feel morally obliged to use more environmental friendly transport modes such as the bike or public transport	*idem*
Most people who are important to me think I should use the car often	*idem*
If car use in general decreases, the air pollution will reduce	*idem*
I think I am responsible to contribute to solutions to problems caused by car use	*idem*
By reducing my car use I can contribute to solutions to the global warming problem	*idem*
Driving the car is typical for me	*idem*
I often choose the car as mode of transportation without realising it in advance	*idem*
I can reduce my car use easily	*idem*
When I use my car often I feel morally aggrieved	*idem*
Most people who are important to me always use the car	*idem*
The national government often does not keep their promises	*idem*

Table B4 Household questionnaire 3: short-term behavioural changes (shopping)

Questions/Variables	Response categories/scales
• GENERAL (PERSONAL) QUESTIONS	• GENERAL (PERSONAL) QUESTIONS
Age (derived from year of birth)	… years
Gender	male; female
Size household	… persons
Paid job	yes; no
Average number of days per week with the car to work	… days per week
Name of other city where shopping is done most often	…
Annual car kilometres	0-5,000; 5,000-10,000; 10,000-15,000; 15,000-20,000; 20,000-25,000; > 25,000
Number of inhabitants in place employee lives (not the municipality) + qualitative description of size (e.g. big city, rural town)	> 5,000; 5,000-10,000; 10,000-20,000; 20,000-50,000; 50,000-100,000; 100,000-150,000; > 150,000
Highest finished education	Primary school; LBO, MAVO, MULO, VGLO, LAVO; MBO, HAVO, VWO, Gymnasium, MMS, HBS; HBO, university
Income (household gross annual)	< 20,500; 20,500-28,500; 28,500-45,000; 45,000-68,000; > 68,000 euro; don't want to say
Zip code home address	…
• CURRENT SHOPPING CHARACTERISTICS	• CURRENT SHOPPING CHARACTERISTICS
Avg. number of times/week daily-shopping by car	… times per week
When is daily-shopping done most often?	weekend; peak period working days; off-peak periods
Trip chaining daily-shopping trips	mostly combine daily shopping with another trip; mostly make shopping trip separately
Avg. number of times/year shopping by car in another city (recreational but also for buying e.g. clothes, furniture, etc.)	… times per year
When is shopping in another city done most often?	weekend; peak period working days; off-peak periods
• CHANGE IN SHOPPING BEHAVIOUR	•CHANGE IN SHOPPING BEHAVIOUR
Introduction of a kilometer charge or cordon charge (see Table 3.6 for details). Questions were sometimes marginally different dependent on the type of charge (see section 3.4.5)	
Acceptability of the charge	7-point Likert scale (very acceptable – very unacceptable)
Times/week less often daily-shopping by car	… on average times per week less often
Division of intended trips changed over alternatives:	
Daily shopping more often by public transport	… times per week
Daily shopping more often by bike, foot	*idem*
Daily shopping more often in off-peak or weekend	*idem*
Combine daily shopping trips more with other trips	*idem*
Daily shopping more often by car closer to home	*idem*

Questions/Variables	Response categories/scales
Do daily shopping less often	*idem*
Times/year less often shopping by car in another city	… on average times per year less often
Division of intended trips changed over alternatives:	
Shopping (other city) more often by public transport	… times per year
Shopping (other city)more often in off-peak or weekend	*idem*
Shopping (other city) more often by car closer to home	*idem*
Do shopping (other city) less often	*idem*
Most acceptable type of revenues use:	rank 1-5 from most to least acceptable
Revenues go to the government 'treasury'	…
Improve the quality of public transport	…
Invest in infrastructure	…
Reduce current road taxes	…
Reduce current fuel taxes	…

Table B5 Firm questionnaire: short-term and long-term behavioural changes

Questions/Variables	Response categories/scales
• 'GENERAL' QUESTIONS	• 'GENERAL' QUESTIONS
Number of settlements in the Netherlands	… settlements
Number of employees settlement in question	20-49; 50-99; 100-249; 250-499; ≥ 500
Division of employees over categories (%)	management, executives, professionals; supportive; 'on the floor' employees
Main business activity	(business) service; industry/production/construction; wholesale trade; transport/distribution; public sector
Main 'direction' of service	outgoing (employees go to customer); incoming
Geographical operating scale	municipal; provincial/regional, inter-regional; national; international
Accessibility settlement:	
By car/lorry	7-point Likert scale (very bad – very good)
By public transport	*idem*
By bike/foot	*idem*
Extent to which settlement 'faces' congestion	7-point Likert scale (very rare – very often)
Perceived attractiveness location settlement (building and location)	score (1-10)
Importance and score settlement on several characteristics:	
1. Representativity building and location	perceived importance (1-10); score (1-10)
2. Functional housing/workplaces for employees	*idem*
3. Security building and terrain	*idem*
4. Accessibility supply and transport of goods	*idem*
5. Accessibility for employees	*idem*
6. Accessibility for customers	*idem*
7. (Low) costs of building and terrain	*idem*
8. Low) cost of goods transport	*idem*
9. (Low) costs of business trips	*idem*
10.(Low) costs compensation commuting employees	*idem*
11.Proximity to comparable firms	*idem*
12.Proximity to raw materials and subcontractors	*idem*
13.Proximity to knowledge centres/universities	*idem*
14.Flexible laws and legislation	*idem*
15.Contacts with official agencies	*idem*
16.Expansion possibilities within building and on terrain	*idem*
17.Parking facilities	*idem*
18.Supply of well-suited personnel in region	*idem*
19.(Low) competition other firms	
Probability of relocation of the settlement (within 2 years)	7-point Likert scale (very unlikely – very likely)

Questions/Variables	Response categories/scales
Type of compensations offered to employees (asked for three types of employees: *management, supportive, work floor*:	
Compensation for relocation costs	never offered, only under special conditions, always offered
Company/business car	*idem*
Compensation km or fuel costs	*idem*
Compensation costs public transport	*idem*
Flexibility in choosing working times	*idem*
Work at home	*idem*
Perceived acceptability of different uses of the revenues:	
Reduce current fuel taxes	7-point Likert scale (very unacceptable – very acceptable)
Improve the quality of public transport	*idem*
Abolish current road taxes	*idem*
Revenues go to the government 'treasury'	*idem*
Build new infrastructure	*idem*
Reduce income taxes	*idem*
Invest in good information provision (e.g. congestion warning systems) along the roads	*idem*
• ROAD PRICING RELATED QUESTIONS	• ROAD PRICING RELATED QUESTIONS
Introduction of a time differentiated kilometer charge to the respondents (see Table 3.7, 7.2 for details)	
Expectation of an increase in costs due to the kilometer charge for the flowing types of (firm) activities:	
Transportation of goods and products	7-point Likert scale (very strong- very weak increase)
Business travel	*idem*
Commuting travel of employees	*idem*
Expectation of a reduction in congestion problems	7-point Likert scale (very unlikely – very likely)
Acceptability of the charge for the firm settlement	7-point Likert scale (very unacceptable – very acceptable)
Perceived attractiveness location settlement (building and location) after introduction of the kilometer charge	score (1-10)
Change in score of some of the firm characteristics reported above due to the kilometer charge (the previous given score before implementation of the charge was given first to the respondents)	
(Low) cost of goods transport	score after introduction of the charge (1-10)
(Low) costs of business trips	*idem*
(Low) costs compensation commuting employees	*idem*
Accessibility supply and transport of goods	*idem*

Questions/Variables	Response categories/scales
Accessibility for employee	*idem*
Accessibility for customers	*idem*
Expected change in offered employee compensations:	
Compensation for relocation costs	7-point Likert scale (offered far less- far more often)
Company/business car	*idem*
Compensation km or fuel costs	*idem*
Compensation costs public transport	*idem*
Flexibility in choosing working times	*idem*
Work at home	*idem*
Expected effect of the charge on trips (compared to the current situation):	
Business trips by car in general	7-point Likert scale (make far less- far more often)
Business trips by car outside the peak period	*idem*
Business trips by car inside the peak period	*idem*
Car/lorry trips for transportation (of goods) in general	*idem*
Car/lorry trips for transportation outside the peak period	*idem*
Car/lorry trips for transportation inside the peak period	*idem*
Use of ICT as substitute for commuting trips (e.g. telework)	*idem*
Use of ICT as substitute for business trip (e.g. email)	*idem*
Expected likeliness other changes:	
Raise product/service prices	7-point Likert scale (very unlikely – very likely)
Change location within 2 years	*idem*
Recruit personnel more often in the vicinity of the firm	*idem*
Perceived accessibility change due to the kilometer charge:	
No benefits shown	7-point Likert scale (accessibility far worse – far better)
Travel time reliability increases	*idem*
Travel time in congestion reduces with 25 %	*idem*
Travel time in congestion reduces with 50 %	*idem*
Acceptability of the kilometer charge in the case of different types of revenue use:	
Reduce current fuel taxes	7-point Likert scale (very unacceptable – very acceptable)
Improve the quality of public transport	*idem*
Abolish current road taxes	*idem*
Revenues go to the government 'treasury'	*idem*
Build new infrastructure	*idem*
Reduce income taxes	*idem*

Questions/Variables	Response categories/scales
Invest in good information provision (e.g. congestion warning systems) along the roads	*idem*
• QUESTIONS LAST RECRUITED EMPLOYEE	• QUESTIONS LAST RECRUITED EMPLOYEE
This part of the questionnaire focused on the last recruited employee. This is another kind of method to study behavioural effects. Advocates of this method state that firms can indicate (possible) changes in a better way for the concrete case of the last recruited employee (concrete and fresh in the memory). This part has been used by another partner of the MD-PIT project to study effects of road pricing on offered employee compensations.	
Type of function for which the employee was recruited	management; supportive; work floor
Gender employee	male; female
Highest finished education level	primary school; LBO, MAVO; MBO, HAVO, VWO, gymnasium; HBO, university
Age employee	… years old
Estimated travel time employee to the settlement before recruiting	< 20; 20-40; 40-60; > 60 min.
Relocated (or is going to locate) closer to the new job	yes; no
Use of following facilities:	
Compensation for relocation costs	yes; no
Company/business car	*idem*
Compensation km or fuel costs	*idem*
Compensation costs public transport	*idem*
Flexibility in choosing working times	*idem*
Work at home	*idem*
Introduction kilometer charge (same as before)	
Offered facilities if the charge would already have been introduced when the employee was recruited:	
Compensation for relocation costs	yes; no
Company/business car	*idem*
Compensation km or fuel costs	*idem*
Compensation costs public transport	*idem*
Flexibility in choosing working times	*idem*
Work at home	*idem*
Compensation kilometer charging costs	*idem*

Appendix C - Value of time results on the basis of questionnaire 1A

This Appendix presents the results of multinomial logit estimations that were carried out on the basis of the data of household questionnaire 1A, described in section 3.4.2. These models were estimated to obtain insight into the size of the value of time. This information is used in the accessibility sensitivity study in chapter 4 (see section 4.2.2), as well as in chapter 6, section 6.4.4.1, where the values of time estimated on the basis of two stated choice datasets are compared: short-term and long-term choice data.

Two models were estimated and are presented in Table C1. The difference between the two models is that in model M1 an average travel cost variable is included, whereas model M2 draws a distinction between toll and fuel costs. This distinction makes it possible to differentiate the value of time estimates towards the type of trip costs. The corresponding values of time are reported in Table C2. In addition to values of time in the car, values of uncertainty and schedule delay were estimated as well. These results are also reported in Table C2. We did not use these latter values in this thesis.

Table C1: multinomial logit estimation of the influence of car and public transport related trip characteristics

Influence of trip related characteristics for car and public transport (MNL)	**Model M1: average car costs**			**Model M2: toll and fuel costs**		
Attributes	**Coefficient**	**T-value**	**P-value**	**Coefficient**	**T-value**	**P-value**
travel costs car	-0.1118	-18.610	0.0000	-	-	-
toll cost car	-	-	-	-0.0665	-3.563	0.0004
fuel cost car	-	-	-	-0.1151	-18.675	0.0000
travel time car	-0.0211	-18.780	0.0000	-0.0219	-18.797	0.0000
schedule delay early car	-0.0150	-16.164	0.0000	-0.0149	-16.055	0.0000
schedule delay late car	-0.0544	-12.440	0.0000	-0.0532	-12.105	0.0000
uncertainty of travel time car	-0.0090	-7.392	0.0000	-0.0092	-7.531	0.0000
constant public transport (PT)	-0.7958	-7.972	0.0000	-0.7484	-7.388	0.0000
travel costs PT	-0.0196	-2.068	0.0387	-0.0027	-0.236	0.8132
travel time PT	-0.0244	-18.790	0.0000	-0.0252	-18.815	0.0000
schedule delay early PT	-0.0184	-5.110	0.0000	-0.0183	-5.073	0.0000
schedule delay late PT	-0.0118	3.428	0.0006	-0.0117	-3.384	0.0007
adjusted ρ^2	0.0898			0.0900		
-2LogLikelihood	-15472.3			-15468.9		

Table C2: value of time, value of schedule delay and value of uncertainty estimations based on Table C1

Estimations of VOT, VSD and VUNC	VOT (euro/hour)
VOT total sample (total costs)	11.3
VOT total sample (toll costs)	11.4
VOT total sample (fuel costs)	19.8
VSDearly	8.1
VSDlate	29.2
VUNC	4.8

Appendix D - The sensitivity of perceptions of being better or worse off

This Appendix tries to provide insight into the influence of combinations of charges and corresponding travel time gains on commuters' perceptions of being better or worse off due to the implementation of a road pricing measure. Chapter 4, among other things, focused on the sensitivity of accessibility changes to the size of the value of time (VOT) by means of a simulation study. This Appendix, on the other hand, particularly studies how sensitive people's perceptions with regard to being better or worse off are to different combinations of travel time gains and travel costs that vary around a person's individual VOT. If this sensitivity is low this may imply that it is not necessary to put much effort into differentiating VOT's towards various socio-economic and demographic characteristics in an accessibility effect study. It may in that case be better to explore which personal characteristics influence people's perceptions of being off better or worse due to road pricing. In the end, this may result in a kind of perception correction factor in accessibility measures if the aim is to avoid a discrepancy between more objective and perceived accessibility. The sensitivity of the above-mentioned perceptions is studied on the basis of stated preference data. Section D.1 describes the methodology we applied and the data characteristics. Section D.2 analyses the sensitivity results.

D.1 - Data and Methodology

To gain insight into the sensitivity of people's perceptions of being better or worse off due to road pricing two questions were asked in a stated preference questionnaire (i.e. household questionnaire 1B, see chapter 3, section 3.4.3). To 564 (commuter) respondents the following scenario was shown:

Suppose a kilometre charge of.. eurocent/kilometre is implemented during peak hours (during the morning rush hour and during the evening rush hour) and that your commuting travel time (one-way) is reduced by.. minutes (in the morning as well as in the evening peak) as a result of this price measure.

Subsequently, the respondents were asked twice whether they expected their 'situation' to be better or worse as a result of the charge. Answers had to be given on a 7-point ordinal scale ranging from 'I will be considerably better off' to 'I will be considerably worse off'. In the first question, the charge and travel time reduction were selected in such a way that their combination was in accordance with the respondents' personal VOT. Individual VOT's were estimated on the basis of a stated choice experiment we conducted earlier among the same respondents (i.e. household questionnaire 1A, see chapter 3, section 3.4.3). In this experiment respondents were shown (among other things) a choice set consisting of four alternatives built up of commuting-related travel time and cost aspects. Travel time gains and costs were varied in such a way between the four alternatives that a point estimate could be given of the individuals VOT on the basis of the alternative they selected.

The second question was basically the same as the first, the only difference being that approximately half of the respondents (randomly selected) were presented with a travel time gain and charge combination corresponding to 1.5 times their individual VOT. A combination corresponding to 0.75 times the VOT was shown to the other group. This variation around the individual VOT was applied to be able to gain insight into the sensitivity of the respondents' perceptions of being better or worse off to travel time gains.

Three charge levels were used: 2.5, 5 and 7.5 eurocents per kilometre, to allow us also to study the differences due to price level variations[181]. One of the charge levels was randomly selected and presented to the respondents. On the basis of the charge level and the individual VOT the time gain that was to be presented to the respondents was computed. The respondents were also asked to indicate their commuting travel time (in one direction) both in the normal/average situation and in a free flow situation. It was possible that the travel time gain estimated on the basis of the charge level and the individual VOT would be higher than the difference in travel time between the indicated normal and free flow commute travel time in reality. In those situations the difference between the normal and free flow travel time was used as a reference and the charge level was adjusted in such a way that travel time gains in combination with the charge level once again corresponded to the VOT.

The basic idea behind the procedure described above is that respondents should indicate they were neither worse off nor better off as a result of road pricing if the combination of travel time and charge would correspond to their VOT. Then, a deviation from the 'no change' choice would indicate a 'perception effect'. However, a somewhat more critical discussion about the suitability of this approach may be important. An individual value of time basically indicates how much money someone is willing to spend to save a certain amount of travel time. As stated earlier, in this case individual values of time were derived from a choice set consisting of four alternatives with varying travel time and (road pricing) costs. Each alternative corresponded to a VOT. The four VOT's were: 3, 6, 10 and 16 euro/hour. One might perhaps argue, somewhat sceptically, that a procedure that asks people to indicate whether they expect to be worse off or better off, or whether they expect things to remain the same when a certain combination of time gain and travel costs is presented to them is fairly useless, because all it does is validate the respondents' VOT. However, a person's VOT is basically based on travel time and cost perceptions alone, and it does not take into account that person's other perceptions and attitudes, for instance a negative attitude towards road pricing, which may influence the way people think about pricing measures. With the procedure we applied in this section such other perception effects can be taken on board. Nevertheless, a remaining problem is that even though the approach may provide some indication as to the influence of people's perceptions, the results cannot be differentiated towards different 'types of perceptions' that specifically influence the overall perception.

Another critical remark can be made with respect to the consequences of using only four different values of time. It is quite unlikely that the actual VOT of a person is always exactly equal to one of the four values described above. If the point estimate of a certain VOT does not exactly match the actual VOT of the respondent, this may influence the respondent's answer of being better

181 The influence of price differentiation on perceptions of being better or worse off was however not studied within this thesis.

or worse off. A deviation from the 'no change' response (because of a time and cost combination in line with the VOT) may then incorrectly be ascribed to a perception effect. This does not form a major problem if the sensitivity of the perception with regard to being better or worse off is relatively insensitive to the size of the VOT. However, if this sensitivity is high, it may be something to keep in mind when modelling accessibility effects. It is also possible, however, that due to the large number of respondents (i.e. 564) possible over- and underestimations of the 'true' value of time cancel out each others effect. This may mean that the 'non-exactness' problem of the individual VOT estimates is less of a problem than it might at first sight appear to be.

Some final critical remarks can be made with respect to the actual question and price scenario itself. As indicated earlier, a low sensitivity may imply that it is not necessary to put much effort in differentiating VOT's towards different socio-economic and demographic characteristics in an accessibility effect study. It is questionable, however, whether the operationalization of 'being better off or worse off as a result of a kilometre charge' is representative for 'a perceived improving or deteriorating accessibility'. Due to budget limitations with regard to the empirical fieldwork only a limited number of questions could be asked. Asking respondents about their perceived geographical accessibility change was not considered a valid option without having the possibility to explain the researchers' definition of geographical accessibility. Because the location component was clear to respondents (i.e. the questions focused on the trip from home to work or vice versa), being better or worse off seemed to be a reasonable good operationalization with regard to accessibility, which seems to cover all kinds of aspects that influence accessibility, such as resistance and perceptions. Last but not least, a critical remark can be made with respect to the description of the price scenario described at the beginning of this section. The scenario presented only a charge level and a travel time gain due to the charge. Yet, it is questionable whether or not respondents can get a good impression of whether they expect to be better or worse off on the basis of a charge level per kilometre only. It may have been more insightful also to give an indication of the (extra) commuting costs on a monthly basis as a result of the charge as was done in questionnaires that were held later on in the PhD-phase and the results of which are presented in chapters 5 to 7. In conclusion, all critical remarks that can be made regarding the approach we selected indicate that one ought to be careful in drawing too explicit conclusions on the basis of the results presented in section D.2.

D.2 - The sensitivity of perceptions for a combination of charge levels and time gains

As described in chapter 4, section 4.5.1, people could indicate on a 7-category scale whether they expected to be better off or worse off as a result of a pricing scenario. The mean results differentiated towards VOT-share are presented in figure D1. The shares of the individual VOT's on the basis of which the travel time gains and charge level scenarios were constructed are presented on the x-axis. Measurements were carried out for three VOT-shares only: 0.75*VOT, 1*VOT and 1.5*VOT. The response categories are shown on the y-axis. The value of 1 represents the category 'expectation to be considerably better off'; the value of 7 indicates 'expectation to be considerably worse off' and 4 stands for the 'expectation to be neither better nor worse off'. The points in the figure show that the average expectation appears to be rather insensitive to the size of travel time gains. A doubling of travel time gains relative to the price level (i.e. going from 1.5

*VOT to 0.75 *VOT) reduces the mean value from almost 5 to 4.4. Thus, even when the travel time gains are 25 percent higher than what respondents seem to demand on the basis of their individual VOT, their average impression is still that they are slightly worse off.

Although, the three points in the figure give an impression of the sensitivity of the perception of being better off or worse off, it may be interesting to extrapolate the results to see for which time and cost combination the respondents on average expect to be neither worse nor better off. On the basis of three points one can in principle determine whether or not a linear relationship exists. However, three points in general are not enough to determine the exact relation. Therefore, it remains somewhat tricky to determine which type of relationship (if any) exists in this case between the perception of being better off or worse off and the time gain and charge combination. Figure D2 is the same as figure D1, with trend lines being added to extrapolate the results for the three data points. Two trend lines were drawn: a linear function and a logarithmic function. These two trend lines were used because they rather represent two extremes in the exploration, in this case with the linear function being relatively conservative compared to the logarithmic function.

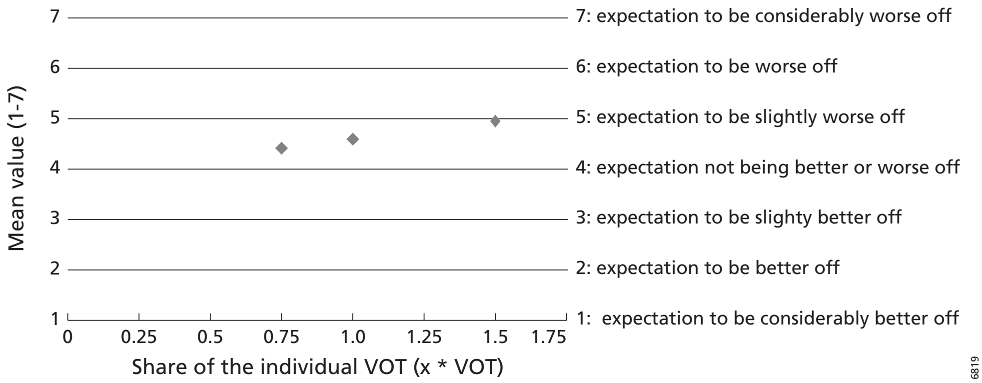

Figure D1: Mean value of being better or worse off dependent on the VOT-share.

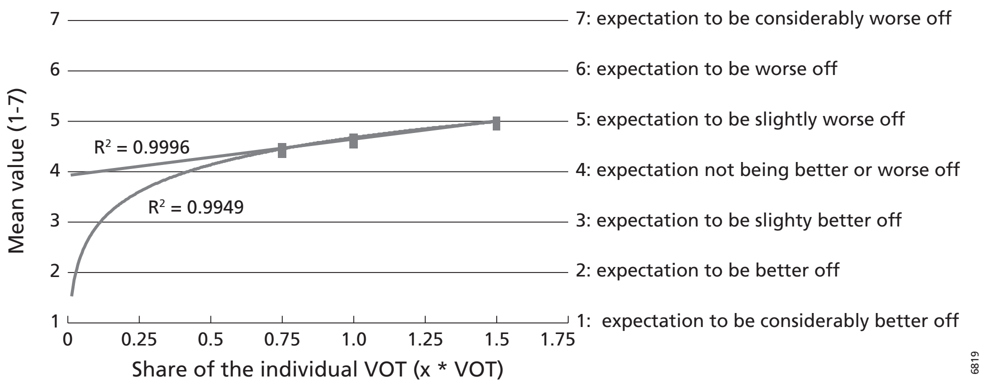

Figure D2: Mean value of being better or worse off dependent on the VOT-share with extrapolation on basis of a linear and logarithmic trend line

Both functions seem to fit well, as indicated by the R^2-value: the linear function has a slightly better fit. Although both trend lines seem to suit the data well, the two exploring relationships lead to different results, especially when the VOT-share is closer to 0. Therefore, the results of the extrapolations must be approached with a certain degree of caution. What we can at least conclude is that for a time cost combination corresponding to a VOT-share that is higher than 0.5*VOT (i.e. time gains are twice as high as one actually demands), respondents on average still have the feeling they will be worse off.

Although the results presented in figure D1 provide some insight into the average 'perception sensitivity', it may be interesting to differentiate the results towards aggregated categories of 'being better off' (i.e. classes 1 to 3), 'being worse off' (5 to 7) and 'no change' (4). If the share of people within each of the three classes is insensitive to travel time changes due to a charge, it may be worthwhile to examine what types of respondents fall into each of the three categories. With this information accessibility measures may be updated to take account of a sort of

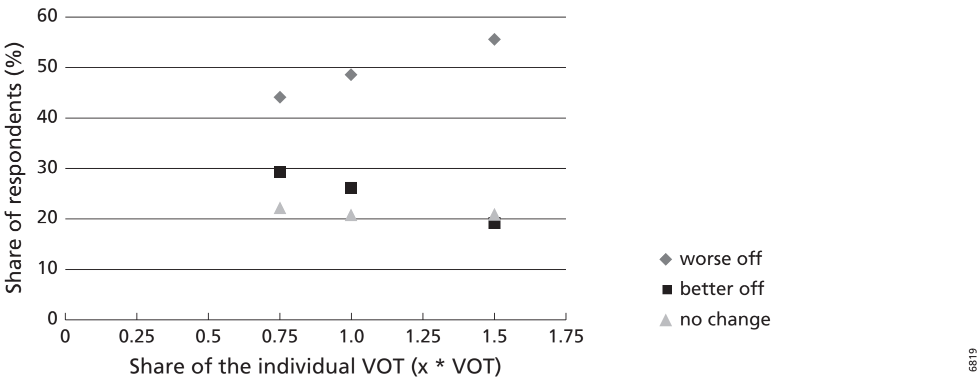

Figure D3: Share of respondents who expect to be better/worse off and the share that awaits no change. Results are differentiated towards the VOT-share.

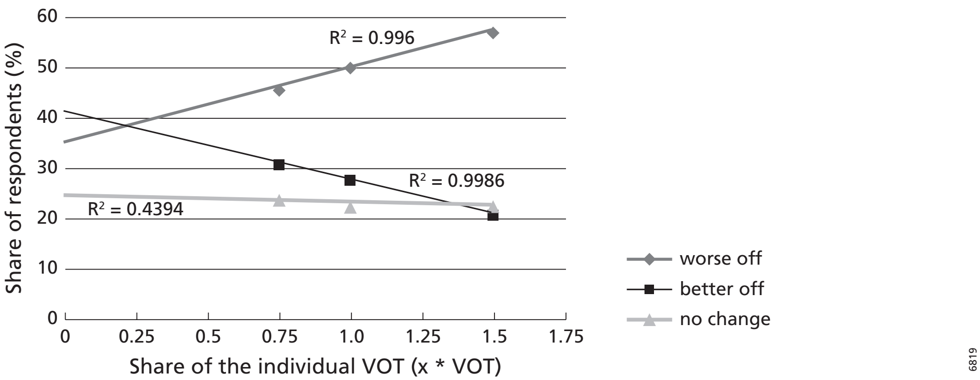

Figure D4: Share of respondents who expect to be better/worse off and the share that awaits no change. Results are differentiated towards the VOT-share and linear trend lines are added for extrapolation.

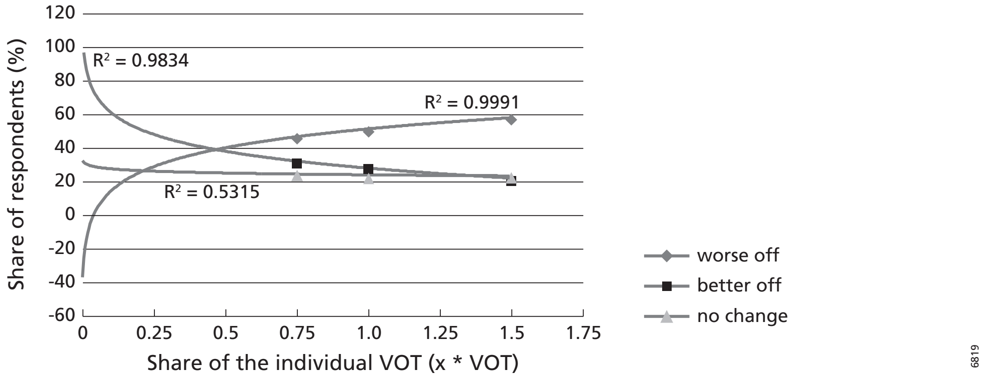

Figure D5: Share of respondents who expect to be better/worse off and the share that awaits no change. Results are differentiated towards the VOT-share and logarithmic trend lines are added for extrapolation.

'perception effect'. Figure D3 indicates the share of the respondents that awaits to be better/ worse off or that expects no change at all. Again the perceptions do not seem to be sensitive to a change in the travel time-cost combination. If time gains are made twice as high (from 1.5 to 0.75*VOT), approximately 10 percent more respondents expect to be better off and 10 percent fewer respondents await to be worse off. The no change option remains stable. On the basis of the data points trend lines were again drawn to extrapolate the results and to find a sort of trade-off VOT-share for which the proportion of people who expect to be worse off is equal to the share that indicate they expect to be better off. For the same reasons as described before, linear and logarithmic trend lines were applied. Linear trend lines are shown in figure D4 and figure D5 provides the logarithmic relationships. In the case of the logarithmic functions the trade-off is close to 0.5*VOT. The less progressive linear function leads to an intersection at 0.25*VOT.

In conclusion, commuters by car appear to be relatively insensitive to travel time gains. It seems that a large share of the respondents who have a certain perception regarding road pricing stick to that perception or are at least not strongly influenced by travel time gains. This would suggest that it may not be necessary to put a great deal of effort in differentiating the cost function towards different values of time may. It could be more worthwhile to gain insight into socio-economic and demographic factors explaining the differences between people's perceptions with regard to being better off or worse off. This information can be used to update the resistance component of accessibility measures if the aim is to decrease a possible existing discrepancy between more objectively measured and perceived accessibility. How to include such a perception component is a topic for further research.

Appendix E - The sensitivity of model outcomes for using Poisson or Tobit regression

As described in section 5.4.1, Tobit regression results on the basis of the absolute (instead of the relative) trip change dependent variable were not presented in chapter 5, since Poisson regression results were more significant. In this Appendix however, such Tobit regression results are presented alongside the outcomes of the Poisson regression. For each of the three trip purposes (commuting, social and other), Poisson and Tobit regression results were estimated with the absolute car trip change as the dependent variable. In this Appendix only the results for commuting are shown (see Table E1) because the same type of sensitivity analyses that were carried out for visit and other trip purposes did not provide (major) additional insights to the insights retrieved from the 'commute' related sensitivity analysis.

Table E1: sensitivity of (explanatory) model outcomes for either using Poisson or Tobit regression analysis

Commute **Sensitivity of explanatory factors for type of estimation**	**M1: absolute change (Poisson regression)**		**M2: absolute change (Tobit regression)**	
	Coeff.	**P-value**	**Coeff.**	**P-value**
Constant	-0.6376	0.0000	-22.3423	0.0000
dummy yearly gross household income (<28.500 euro=1)	-0.4785	0.0000	-3.4280	0.0939
dummy yearly gross household income (28.500-45.000 euro=1)	-0.2630	0.0000	-0.7107	0.6753
dummy yearly gross household income (45.000-68.000 euro=1)	-	-	-	-
dummy yearly gross household income (>68.000 euro=1)	-0.6064	0.0000	-5.6739	0.0093
dummy age respondent (≥ median value of 39 years =1)	-0.2505	0.0000	-1.8033	0.1957
dummy gender (female=1)	-0.3192	0.0000	-3.5645	0.0281
dummy education (college, university=1)	0.3599	0.0000	3.5790	0.0170
dummy yearly km in car (> median value of 15.000 km =1)	0.4276	0.0000	2.3667	0.1908
dummy commute dist. car one-way (> median value of 25 km =1)	0.1424	0.0119	0.2717	0.8637
dummy travel cost compensation employer (completely compens.=1)	-0.7360	0.0000	-5.1000	0.0016
dummy possibility to work ay home (always or sometimes =1)	0.2393	0.0000	3.9722	0.0114
dummy car low weight (yes=1)	0.6348	0.0000	6.1411	0.0007
dummy heavy car (yes=1)	0.3944	0.0000	1.5276	0.3878
dummy price measure 1	0.3658	0.0003	2.2243	0.3352
dummy price measure 2A	1.0918	0.0000	8.6487	0.0007
dummy price measure 3	1.3650	0.0000	11.4641	0.0000
sigma	-		15.2425	0.0000
N (number of choices)	1137		1137	
N (number of respondents)	379		379	
Log likelihood	-4068.2		-	
Log likelihood (convergence)	-3520.5		-1082.3	
X^2	1095.5		-	

The overall picture that emerges form Table E1 is that when using Poisson regression, more significant influencing factors are observed than when Tobit regression is applied. It also appears that the sign of the explanatory variables remains the same. For the motive 'other trips', however, one variable had a different coefficient sign in the Tobit compared to the Poisson model. That variable was statistically insignificant in the Tobit model.

Appendix F - Factor analysis on settlement characteristics firms

Firm representatives were asked to rate their settlement on a scale from 1 to 10 on a total of 19 characteristics, which may influence their firm's behaviour. A factor analysis was applied to these 19 characteristics to identify a small number of factors that explain most of the variance observed in the 19 variables (see also SPSS Help Topics, 2006; Grimm and Yarnold, 1995; Zandvliet and Dijst, 2005). Emerging factors were subsequently used as independent variables in chapter 7 to explain the differences in the perceived accessibility change as a result of to the kilometre charge on the one hand, and to study the influence of these new factors on the probability to relocate due to the kilometre charge on the other hand.

To carry out a factor analysis, the 'input' variables must be measured quantitatively at the interval or ratio level. In fact, the scale we used, from 1 to 10 with integers only, is not of an interval or ratio level, but of an ordinal level. However, because of the relatively broad range of the ordinal scale, it was considered legitimate to carry out a factor analysis. The factor analysis procedure offers a high degree of flexibility (SPSS, 2006): different methods for extraction and rotation are available. Within this Appendix only the techniques we used and the results are reported, without explicitly motivating every choice. The reason for this is that the extraction method we used and the rotation applied can be seen as quite standard when applying a factor analysis.

The extraction method applied is the principal component analysis (PCA). This technique extracts principal components, also called eigenvectors. Only eigenvectors larger than 1 were taken into account (in accordance to Kaisers stopping rule: see Grimm and Yarnold, 1995). Additionally, a varimax rotation was applied, which focuses on making as many variables in each column of the factor loading coefficient Table as close to zero as possible (Grimm and Yarnold, 1995). This makes it easier to interpret (classify) the eigenvectors. Table F1 shows the results of the factor analysis. Five factors with an eigenvalue larger than 1 emerged, explaining 56.4 percent of the total variance. The scree test, which is an alternative method that can also be used to determine at how many factors the analysis must be stopped, also confirmed five variables to be the 'best' choice. Within Table F1 only relatively high factor loading coefficients ($\geq|0.50|$) are displayed. This makes the interpretation of the five factors easier. A loading coefficient of 0.50 means that the variable and the eigenvector share $(0.50)^2 * 100$ percent, or 25 percent of their variance.

Table F1 shows that the first eigenvector scores well on several building characteristics and on accessibility of the settlement. Therefore this first factor has been labelled as: 'Building characteristics and accessibility'. All kind of settlement related cost factors share a large part of their variance with the second factor. That is why this second factor is termed 'Firm costs'. Furthermore, the third variable scores well on nearness to business related characteristics ('Proximity to business relations'). Following the same procedure, factors 4 and 5 are respectively labelled 'Regulation and contacts' and 'Expansion and parking possibilities'. For each respondent, finally, five factor regression scores were computed (i.e. one for each factor), which formed the

Table F1: factor scores and resulting five factors that emerge from the factor analysis

Characteristics	**Factor**				
	1	**2**	**3**	**4**	**5**
Representativity building and location	0.679				
Functional housing/workplaces for employees	0.721				
Security building and terrain	0.583				
Accessibility supply and transport of goods					
Accessibility for employees	0.688				
Accessibility for customers	0.697				
(low) costs of building and terrain		0.544			
(low) cost of goods transport		0.663			
(low) costs of business trips		0.691			
(low) costs compensation commuting employees		0.670			
Nearness of comparable firms			0.754		
Nearness of raw materials and subcontractors			0.825		
Nearness of knowledge centres/universities			0.685		
Flexible laws and legislation				0.775	
Contacts with official agencies				0.572	
Expansion possibilities within building and on terrain					0.726
Parking facilities					0.669
Supply of well-suited personnel in region					
(low) competition other firms					

Factor 1: Building characteristics and accessibility
Factor 2: Firm costs
Factor 3: Nearness of business relations
Factor 4: Regulation and contacts
Factor 5: Expansion and parking possibilities

basis for the construction of independent explanatory dummy variables that were tested in chapter 7 (sections 7.3.3 and 7.5.3).

Samenvatting

Op steeds meer plaatsen in de wereld worden wegbeprijzingsmaatregelen ingevoerd of wordt overwogen dat te doen. Daarvoor zijn verschillende redenen aan te voeren. Een belangrijke reden is om externe kosten veroorzaakt door wegverkeer te verzachten of in ieder geval op een eerlijkere manier te verdelen over de veroorzakers van die effecten. Externe kosten ontstaan wanneer het welzijn van een individu (of de maatschappij) wordt aangetast door activiteiten van iemand anders die deze 'spill-over' effecten niet meeneemt in zijn/haar beslissing(en) om iets te doen. Voorbeelden van externe kosten in het wegverkeer zijn filekosten, kosten als gevolg van verkeersongelukken maar bijvoorbeeld ook milieu- en omgevingskosten zoals luchtvervuiling, verzuring, geluidsoverlast enzovoort. Daarnaast kunnen beprijzingsmaatregelen ook worden ingevoerd om opbrengsten te genereren. Deze opbrengsten kunnen dan bijvoorbeeld gebruikt worden voor het financieren van onderhoud aan wegen, het aanleggen van nieuwe infrastructuur maar ook voor totaal andere doeleinden die niets met verkeer te maken hebben.

Wanneer we ons richten op de fileproblematiek dan blijkt dat wegbeprijzing gezien wordt als een veelbelovende maatregel om files te bestrijden. Dit is niet alleen het geval in andere landen, zoals in Engeland of Singapore, waar inmiddels op een succesvolle wijze prijsmaatregelen zijn ingevoerd, maar ook in Nederland. Maar ondanks voorstellen om een vorm van wegbeprijzing in Nederland in te voeren (bijvoorbeeld het Rekeningrijden-voorstel van Minister Netelenbos in het tweede paarse kabinet) is er tot op heden door het parlement geen formeel besluit genomen om een vorm van beprijzing te implementeren. Een gebrek aan acceptatie is een mogelijk belangrijke oorzaak hiervoor. Onder zowel burgers als bestuurders bestaat het idee dat wegbeprijzing niets anders zal doen dan mensen extra te laten betalen voor het (al niet 'goedkope') bezit en gebruik van de auto. Dit beeld wordt mogelijkerwijs mede ingegeven door het feit dat niet duidelijk is wat de precieze effecten zijn van een bepaalde prijsmaatregel. Het is bijvoorbeeld minder goed onderzocht in welke mate verschillende mensen en bedrijven hun korte en/of lange termijn gedrag aanpassen. Dit proefschrift heeft beoogd meer inzicht te verschaffen in deze effecten en in hoe deze effecten bepaald kunnen worden. Daarbij is voornamelijk uitgegaan van een transport geografisch perspectief.

Dit geografische perspectief is uitgewerkt in twee onderzoekslijnen. De eerste onderzoekslijn heeft zich gericht op geografische bereikbaarheid. Terwijl economische analyses geschikt zijn om (gemiddelde) welvaartseffecten als gevolg van wegbeprijzingsmaatregelen te bepalen, bieden dit soort analyses geen inzicht in hoe wegbeprijzing de bereikbaarheid van verschillende typen mensen op verscheidene locaties beïnvloedt. Vanuit een beleidsoogpunt zou het interessant kunnen zijn om dit soort gedifferentieerde bereikbaarheidseffecten te bepalen voordat een beprijzingsmaatregel daadwerkelijk wordt ingevoerd. Dit kan worden gedaan in aanvulling op economische welvaartsanalyses. Geografische bereikbaarheidsuitkomsten zouden dan bijvoorbeeld kunnen helpen om beprijzingsmaatregelen verder te 'fine tunen'.

Ondanks de mogelijke voordelen van het gebruik van geografische bereikbaarheid in beleidsevaluaties, zijn geografische bereikbaarheidsmaten voorzover bekend (nog) niet gebruikt om effecten van wegbeprijzing te evalueren. Dit kan deels veroorzaakt zijn doordat geografische bereikbaarheidsmaten in hun 'basale' vorm niet direct toepasbaar zijn voor het evalueren van beprijzingseffecten. In praktische applicaties worden over het algemeen bereikbaarheidsmaten toegepast die gebaseerd zijn op reistijd of afstand. Maar, voor het kunnen bepalen van bereikbaarheidseffecten (als gevolg) van wegbeprijzing is een bereikbaarheidsmaat nodig die op transportkosten is gebaseerd. Maar hoe kunnen bereikbaarheidseffecten als gevolg van wegbeprijzing dan het beste worden bepaald? Een toegevoegde waarde van deze studie is dat onderzocht is welke geografische bereikbaarheidsmaten in het bijzonder geschikt zijn om bereikbaarheidseffecten als gevolg van wegbeprijzing te bepalen. Verder zijn in deze studie de benodigde verfijningen aan bereikbaarheidsmaten onderkend en is bekeken hoe bereikbaarheidseffecten vanuit een praktisch oogpunt kunnen worden bepaald. Meer specifiek is het eerste doel van dit onderzoek om:

Inzicht te verschaffen in hoe realistische geografische bereikbaarheidseffecten als gevolg van wegbeprijzingsmaatregelen gemodelleerd moeten worden door (1) allereerst theoretisch vast te stellen welke bereikbaarheidsindicatoren geschikt zijn om te gebruiken, hoe de weerstandsfunctie van indicatoren gespecificeerd moet worden en met welke processen rekening moet worden gehouden en door (2) in de tweede plaats praktisch (door middel van een gevoeligheidsanalyse) vast te stellen hoe gevoelig berekende bereikbaarheidseffecten zijn voor de prijsmaatregel en aan de bereikbaarheidsindicator gerelateerde (invoer)karakteristieken.

De analyse heeft zich erop gericht om op basis van state-of-the-art modellen inzichtelijk te maken welke typen prijsmaatregelen (en prijshoogtes) tot hogere bereikbaarheidswinsten of -verliezen leiden dan anderen. Bovendien, is via de analyse geprobeerd om meer te weten te komen over hoe belangrijk het is om de weerstandsfunctie van geografische bereikbaarheidsindicatoren (dat wil zeggen de moeite die het kost om iets te bereiken) onder te verdelen in verschillende kostenvariabelen (bijvoorbeeld niet alleen beprijzingskosten maar ook benzinekosten), persoonskarakteristieken en aanvullend om het belang van de keuze van het type bereikbaarheidsindicator voor de uitkomsten vast te stellen.

Terwijl de eerste onderzoekslijn zich bezig heeft gehouden met geografische bereikbaarheid, heeft de tweede onderzoekslijn voornamelijk ten doel gehad om meer inzicht te verschaffen in de intenties van huishoudens en bedrijven om als gevolg van wegbeprijzing hun gedrag te veranderen. De studie heeft zich voornamelijk gericht op lange termijn gedragseffecten (herlocaties) van huishoudens en bedrijven. Korte termijn veranderingen in de gemaakte autoritten zijn echter ook geanalyseerd, aangezien het in de verwachting ligt dat langere termijn beslissingen niet onafhankelijk zijn van korte termijn veranderingen (of veranderingsmogelijkheden) in het rittenpatroon van huishoudens en bedrijven. Het doel met het oog op de tweede onderzoekslijn is:

Het verschaffen van inzicht in gedragsmatige effecten, voornamelijk (her)locatiekeuzes van huishoudens en bedrijven, als gevolge van (verschillende) wegbeprijzingsmaatregelen.

Met betrekking tot het bestuderen van gedragseffecten is deze studie in verschillende opzichten innovatief. Allereerst zijn de intenties om als gevolg van beprijzing van gedrag te gaan veranderen onderzocht op basis van empirische (stated preference) data. Dit soort empirisch bewijs is tot nog toe slechts zeer beperkt aanwezig. In de tweede plaats heeft deze studie zich vooral gericht op de (langere termijn) locatie-effecten van wegbeprijzing. Deze effecten zijn nog nauwelijks onderzocht. Ten derde zijn naast de locatie-effecten tegelijkertijd voor dezelfde respondenten ook de (korte termijn) autoriteffecten onderzocht. Dit is voorzover bekend de eerste studie die zowel korte als lange termijn effecten tegelijkertijd bestudeert. Twee andere innovatieve aspecten zijn verder dat (i) de intenties om het gedrag te veranderen systematisch bestudeerd zijn voor verschillende typen prijsmaatregelen met variërende prijshoogten en typen opbengstgebruik (dat wil zeggen opbrengsten van de prijsmaatregel) en dat (ii) intenties om huidige autoritten te veranderen niet alleen bestudeerd zijn voor woon-werk verkeer maar ook voor andere ritmotieven: bezoekverkeer, andere ritten (dan woon-werk en bezoek) en winkelritten (als een speciale vorm van 'andere' ritten). Een toegevoegde waarde van dit onderzoek aan de bestaande literatuur tot slot is dat ook onderzocht is welke typen mensen en bedrijven (met hun eigen kenmerken) meer of minder van plan zijn om hun gedrag op de korte en langere termijn aan te passen. Dit is onderzocht op basis van 'state-of-the-art' statistische technieken.

Om de twee doelen te bereiken zijn vier onderzoeksvragen geformuleerd. De eerste twee hebben betrekking op het eerste en de laatste twee op het tweede doel. De onderzoeksvragen luiden als volgt:

1. In welke mate zijn bestaande geografische bereikbaarheidsindicatoren toepasbaar voor het modelleren van bereikbaarheidseffecten als gevolg wegbeprijzing en welke aspecten en processen moeten in beschouwing worden genomen om 'realistische' bereikbaarheidseffecten als gevolg van wegbeprijzing te modelleren?
2. In welke mate zijn berekende geografische bereikbaarheidseffecten als gevolg van wegbeprijzing gevoelig voor variërende kostengerelateerde (type prijsmaatregel, heffingshoogte, specificatie van de gegeneraliseerde transportkostenfunctie) en niet-kostengerelateerde (type bereikbaarheidsindicator, weerstandsparameter en netwerk detail) aspecten en wat zijn de gevolgen daarvan voor het modelleren van geografische bereikbaarheidseffecten als gevolg van wegbeprijzing?
3. In welke mate beïnvloeden wegbrijzingsmaatregelen het rittenpatroon en de (her)locatiekeuzes, vooral de werk- en woonlocaties, van huishoudens?
4. In welke mate beïnvloedt wegbeprijzing de perceptie van bereikbaarheid van bedrijven en hun korte termijn (ritten, werknemerscompensaties) en lange termijn (herlocatie) gedrag?

Deze onderzoeksvragen zijn beantwoord in de verschillende hoofdstukken van dit proefschrift. In totaal bestaat het proefschrift uit acht hoofdstukken. De eerste drie hoofdstukken vormen het theoretische kader, waarbij hoofdstuk 1 het introductiehoofdstuk is, hoofdstuk 2 ingaat op de theorie en in hoofdstuk 3 het onderzoeksontwerp en de onderzoeksmethoden uiteengezet worden. Hoofdstuk 2 beantwoordt tevens onderzoeksvraag 1. Hoofdstuk 4 heeft de gevoeligheid van berekende bereikbaarheidsuitkomsten bestudeerd, daarmee onderzoeksvraag 2 beantwoordend. In hoofdstuk 5 tot en met 7 zijn de gedragsmatige effecten geanalyseerd. Meer specifiek zijn de gedragsveranderingen in het rittenpatroon van huishoudens geanalyseerd in hoofdstuk 5. Herlocatie-effecten van huishoudens zijn bestudeerd in hoofdstuk 6. Tezamen beantwoorden hoofdstuk 5 en 6 onderzoeksvraag 3. Gedragsveranderingen van bedrijven zijn geanalyseerd in hoofdstuk 7 om daarmee een antwoord te kunnen geven op de vierde en laatste onderzoeksvraag. Hoofdstuk 8 tenslotte vat de resultaten samen, concludeert, geeft beleidsaanbevelingen en doet voorstellen voor verder onderzoek. Hieronder volgen achtereenvolgens de belangrijkste conclusies en beleidsaanbevelingen. Met betrekking tot de conclusies komen eerst de algemene hoofdconclusies of -constateringen aan bod. Daarna worden per 'thema' meer specifieke conclusies gegeven.

Hoofdconclusies en -constateringen

Op basis van deze studie zijn de volgende drie hoofdconclusies geformuleerd:

- Deze studie heeft laten zien dat het mogelijk is om bereikbaarheidseffecten als gevolg van wegbeprijzing op een relatief eenvoudige wijze te bepalen met toegesneden geografische bereikbaarheidsmaten. Bereikbaarheidseffecten zijn echter wel gevoelig voor hoe bereikbaarheid berekend wordt.
- Huishoudens zijn van plan hun gedrag aan te passen wanneer een wegbeprijzingsmaatregel wordt ingevoerd. Zoals kon worden verwacht zijn meer mensen van plan om veranderingen in hun autoritten door te voeren dan in de locaties waar ze wonen en werken. Hoe dan ook, herlocaties als gevolg van wegbeprijzing lijken te gaan voorkomen en zijn niet verwaarloosbaar.
- Net als voor huishoudens geldt ook dat meer bedrijven als gevolg van wegbeprijzing veranderingen in hun ritten dan in hun vestigingslocatie(s) doorvoeren. Wederom zijn de herlocaties echter niet verwaarloosbaar.

Modellering van bereikbaarheidseffecten als gevolg van wegbeprijzing (onderzoeksvragen 1 en 2)

De eerste onderzoeksvraag is beantwoord op basis van een literatuuronderzoek aangevuld met inzichten in gedragsmatige effecten van huishoudens als gevolg van wegbeprijzing. Voor het verkrijgen van inzicht in de gevoeligheid van bereikbaarheidsuitkomsten (onderzoeksvraag 2) is vervolgens gebruik gemaakt van een simulatieonderzoek. De volgende conclusies zijn uit de bereikbaarheidsstudie naar voren gekomen:

- Contour- en potentiaalmaten zijn geschikte maten om bereikbaarheidseffecten als gevolg van een prijsmaatregel te berekenen.

Er bestaan verschillende typen geografische bereikbaarheidsindicatoren. Op basis van een multi-criteria analyse is naar voren gekomen dat klassieke geografische bereikbaarheidsindicatoren zoals de contour- en de potentiaalmaat geschikte maten zijn om bereikbaarheidseffecten als gevolg van een prijsmaatregel te berekenen. Dit soort indicatoren bestaat uit een locatiecomponent aan de ene kant (activiteitenlocaties) en uit een weerstandsfunctie aan de andere kant (de moeite om de verschillende locatie te bereiken). Reistijd is een belangrijke weerstandscomponent. Door gebruik te maken van een gegeneraliseerde transportkostenfunctie kan reistijd uitgedrukt worden in kosten. Dit kan worden bereikt door reistijd te vermenigvuldigen met een monetaire waardering voor reistijd(winst): de zogenaamde value of time. Een extra kostencomponent als gevolg van wegbeprijzing kan dan eenvoudig worden toegevoegd aan de weerstandsfunctie. De kosten voor beprijzing beïnvloeden de weerstandsfunctie op een directe wijze. Dit kan worden aangemerkt als een eerste orde effect.

- Om 'realistische' bereikbaarheidseffecten als gevolg van wegbeprijzing te berekenen is het goed om de gegeneraliseerde transportkostenfunctie van bereikbaarheidsmaten te differentiëren naar de value of time beïnvloedende factoren.

Het is vanuit een theoretisch oogpunt belangrijk om de gegeneraliseerde transportkostenfunctie te differentiëren, omdat verschillende typen mensen reistijd anders waarderen en dus ook op een verschillende manier beïnvloed worden door een prijsmaatregel. Daar komt bij dat in de gevoeligheidsanalyse is gebleken dat bereikbaarheidsuitkomsten als gevolg van prijsbeleid gevoelig zijn voor variaties in de reistijdwaardering. De theoretische motieven en praktische gevoeligheid in uitkomsten wijzen er dus op dat het belangrijk is om verschillende reistijdwaarderingen mee te nemen. Differentiatie naar een belangrijke variabele als bijvoorbeeld inkomen zou het realisme van bereikbaarheidseffecten waarschijnlijk al duidelijk kunnen verbeteren.

- Vanuit een praktisch oogpunt is het verstandig om realistische bereikbaarheidseffecten te berekenen voor de grote groep mensen die als gevolg van een wegbeprijzingsmaatregel (bijna) niet van plan zijn om hun rittengedrag met de auto aan te passen. De omvang van het welvaartsverlies van de mensen die hun 'autogedrag' wel aanpassen zou relatief eenvoudig bepaald kunnen worden door gebruik te maken van de economische 'rule-of-half'.

Als gevolg van prijsbeleid zullen er mensen zijn die hun gedrag op de korte (bijvoorbeeld veranderingen in het rittenpatroon) en/of lange termijn (bijvoorbeeld verhuizen) aanpassen. Gedragsaanpassingen kunnen worden opgevat als tweede orde effecten. Deze effecten kunnen vervolgens de bereikbaarheid beïnvloeden. Om realistische bereikbaarheidseffecten te kunnen berekenen moet de invloed van deze gedragsveranderingen worden meegenomen. Niettemin is in het onderzoek gebleken dat het merendeel van de huidige ritten met de auto niet wordt aangepast als gevolg van prijsbeleid: meer dan 85 procent van de autoritten worden niet veranderd. Wanneer vervolgens een afweging moet worden gemaakt tussen de moeite die het kost om (alle) gedragsveranderingen nauwkeurig te modelleren en de extra winst die dat oplevert in het realisme van bereikbaarheidsuitkomsten, dan lijkt het nuttig om vooral bereikbaarheidseffecten te modelleren voor de groep mensen (85 procent van de ritten) die niet van gedrag gaat veranderen. Om voor deze groep realistische bereikbaarheidseffecten te berekenen moeten (persoonlijke) baten van beprijzing worden meegenomen. Een belangrijke batencomponent is de mogelijke reistijdverandering veroorzaakt door mensen die wel van gedrag veranderen. Deze reistijdveranderingen kunnen worden bepaald door gebruik te maken van een verkeerskundig simulatiemodel. Wanneer dezelfde aanpak ook wordt gehanteerd voor mensen (maximaal 15 procent van de ritten) die daadwerkelijk van gedrag veranderen (dat wil zeggen uitgaan van de paradox dat deze mensen niet van gedrag veranderen, maar tegelijkertijd wel profiteren van de reistijdwinsten veroorzaakt door henzelf), dan worden bereikbaarheidsverliezen voor deze mensen overschat en mogelijke winsten onderschat. Het optreden van deze overschatting van negatieve bereikbaarheidseffecten moet tenminste worden aangekaart wanneer resultaten worden gerapporteerd. Een relatief eenvoudige manier om een geaggregeerde kwantitatieve inschatting van de welvaartsverliezen voor deze laatstgenoemde groep van mensen te kunnen geven is door gebruik te maken van de economische 'rule-of-half'.

- Berekende bereikbaarheidseffecten als gevolg van wegbeprijzing zijn gevoelig voor het variëren van het type beprijzingsmaatregel en voor de hoogte van de heffing.

Een kilometerheffing die naar plaats en tijd is gedifferentieerd leidt tot hogere reistijdwinsten en lagere bereikbaarheidsverliezen (of hogere winsten) dan eenzelfde kilometerheffing die alleen naar tijd is gedifferentieerd. Dit bevestigt de algemene verwachting dat een meer gedifferentieerde heffing effectiever is in het bestrijden van fileproblemen. Verder is, zoals op basis van de economische welvaartstheorie te verwachten valt, gebleken dat reistijdwinsten alleen niet opwegen tegen de extra heffingskosten noch voor de naar tijd noch voor de naar tijd en plaats gedifferentieerde heffing.

Naast het type maatregel is verder ook de invloed van de heffingshoogte geanalyseerd. Er is gebleken dat bereikbaarheidsuitkomsten gevoelig zijn voor het veranderen van de hoogte van de heffing. Een hogere heffing hoeft niet tot hogere bereikbaarheidswinsten (of lagere bereikbaarheidsverliezen) te leiden. Er deed zich juist het tegenovergestelde voor: hogere tijdgedifferentieerde kilometerheffingen resulteerden in grotere bereikbaarheidsverliezen dan lagere heffingen.

- Berekende bereikbaarheidseffecten zijn gevoelig voor het type bereikbaarheidsmaat dat gebruikt wordt. Dit impliceert dat het goed is om zowel de potentiaal- als de contourmaat te gebruiken om zo een gedegen inzicht te krijgen in de bereikbaarheidseffecten als gevolg van wegbeprijzingsmaatregelen.

De gevoeligheid van de resultaten voor het type bereikbaarheidsmaat dat gebruikt wordt is voornamelijk het gevolg van de (wiskundige) formulering van de bereikbaarheidsmaat. Omdat de gevoeligheid van de resultaten groot is moet men van tevoren heel goed weten waarom men specifiek één bepaalde bereikbaarheidsmaat zou willen gebruiken. Is dat niet bekend dan is het waarschijnlijk beter om meerdere maten toe te passen om op die manier een meer gedegen inzicht te krijgen in de 'bandbreedte' van de bereikbaarheidseffecten als gevolg van wegbeprijzing.

Gedragsveranderingen huishoudens (onderzoeksvraag 3)
De gedragsveranderingen van huishoudens zijn geanalyseerd in hoofdstuk 5 (veranderingen in het rittenpatroon) en hoofdstuk 6 (locatieveranderingen). Beide hoofdstukken samen beantwoorden de derde onderzoeksvraag. Om inzicht te verkrijgen in de gedragseffecten zijn meerdere stated preference onderzoeken uitgevoerd. De belangrijkste conclusies met betrekking tot gedragsveranderingen van huishoudens zijn verdeeld over drie delen: (i) veranderingen in het rittengedrag met de auto, (ii) de waarschijnlijkheid dat huishoudens zich elders vestigen of een andere baan zoeken en (iii) verklarende variabelen voor gedragsveranderingen.

Veranderingen in het rittengedrag met de auto

- De grootste veranderingen in de huidige gemaakte autoritten vinden plaats voor boodschap- en winkelritten, respectievelijk gevolgd door bezoek gerelateerde, andere (dat wil zeggen anders dan bezoek of woon-werk) en ritten met een woon-werk motief.

Veranderingen in de autoritten voor winkelen of boodschappen doen zijn op basis van een andere dataset bestudeerd dan de veranderingen in autoritten met bezoek, woon-werk of andere motieven. De gevonden grotere aanpassingen in de huidige autoritten voor winkelen/boodschappen doen zijn waarschijnlijk het gevolg van het feit dat veranderingen in winkelritten niet alleen voor een tijdgedifferentieerde kilometerheffing zijn gevraagd maar ook voor een cordonheffing rond grote steden. Een dergelijke cordonheffing is niet voorgelegd aan respondenten in de andere vragenlijst (dat wil zeggen de vragenlijst met betrekking tot de andere drie ritmotieven). De cordonheffing resulteert in een grotere geneigdheid tot verandering. Dit kan mogelijkerwijs veroorzaakt worden doordat de naar plaats gedifferentieerde cordonheffing makkelijker te ontwijken is dan een kilometerheffing op alle wegen. Daarnaast kan er ook een psychologische drempel bestaan om de cordonheffing, waarbij een tol op één bepaalde plaats geheven wordt, te passeren.

Omdat woon-werk ritten relatief vaak voorkomen, in het algemeen langer zijn dan bezoek of andere ritten en geregeld plaatsvinden tijdens de drukke (spits)perioden, zullen veranderingen in woon-werk ritten waarschijnlijk toch een grotere invloed (dan andere type ritten) hebben op reis- en verliestijden in gebieden die te maken hebben met fileproblemen.

- De meest effectieve beprijzingsmaatregel om huidige autoritten van huishoudens te veranderen is een naar tijd gedifferentieerde kilometerheffing. Dit althans in vergelijking tot andere (kilometergebaseerde) prijsmaatregelen, zoals (i) een platte (ongedifferentieerde) heffing plus een naar tijd gedifferentieerde tol voor het passeren van knelpunten, (ii) een platte kilometerheffing en (iii) een kilometerheffing die afhankelijk is van het gewicht van de auto.

De naar tijd gedifferentieerde heffing zorgt ervoor dat bijna 15 procent van de huidige woon-werk en 'bezoek' gerelateerde autoritten wordt aangepast. Voor ritten met een ander motief (dan woon-werk of bezoek) komt dit neer op ongeveer 13 procent. Afgezien van deze heffing, is de platte heffing plus een knelpuntheffing het meest effectief althans voor zover het een verandering van woon-werk ritten betreft: 11 procent van de huidige autoritten worden aangepast. Een platte kilometerheffing blijkt echter effectiever te zijn in het beïnvloeden van bezoek en andere ritten: 14 procent van de bezoekritten en 11 procent van de overige ritten worden als gevolg van deze heffing aangepast. Van alle geteste maatregelen is de naar voertuiggewicht gedifferentieerde heffing het minst effectief gebleken in het veranderen van huidige autoritten. Verder is uit de analyses naar voren gekomen dat niet alle mensen van plan zijn om minder autoritten te maken of om helemaal niets te veranderen. Gemiddeld slechts 0.5 procent van alle respondenten denkt meer autoritten te gaan maken wanneer een prijsmaatregel wordt ingevoerd. Deze mensen verwachten mogelijkerwijs dat de voordelen van beprijzing (bijvoorbeeld de gemonetariseerde reistijdwinsten) opwegen tegen de heffingskosten.

- Het type prijsmaatregel beïnvloedt in sterke mate de gekozen alternatieven voor de huidig gemaakte autoritten.

Voor de naar tijd gedifferentieerde (kilometer)heffingen geldt dat een verandering in tijdstip van rijden het meest gekozen alternatief is voor de huidige autoritten. Voor niet naar tijd gedifferentieerde heffingen is gevonden dat openbaar vervoer (alleen voor woon-werk) en langzaam verkeer (fiets en/of lopen) het meest als alternatief worden gekozen. Voor bezoek- en overige ritten geniet het gebruik van langzaam verkeer veel vaker de voorkeur dan openbaar vervoer.

- Een vermindering van het aantal te maken ritten (dat wil zeggen een verlaging van de vraag) wordt alleen vaak gekozen voor niet woon-werk motieven.

Woon-werk ritten zijn in zijn algemeenheid waarschijnlijk moeilijker aan te passen dan andere ritten, zoals voor bezoek, winkel en andere motieven. Mensen hebben bijvoorbeeld niet allemaal de mogelijkheid om (vaker) thuis te werken of hun werkuren flexibel in te delen (bijvoorbeeld minder dagen werken, maar wel langer per dag).

- Voor winkelritten die op dit moment naar een andere stad dan waar de respondent woont worden gemaakt, is het vaker winkelen op locaties dichterbij huis een veel gekozen alternatief (20 tot 25 procent van de huidige winkelritten met de auto).

Herlocaties huishoudens

- De waarschijnlijkheid dat huishoudens als gevolg van wegbeprijzing een andere baan zoeken (dichterbij waar ze wonen) is gemiddeld hoger dan de waarschijnlijkheid dat ze gaan verhuizen (naar een locatie dichterbij het werk).

Afgezien van veranderingen in de ritten die gemaakt worden is ook de waarschijnlijkheid onderzocht dat mensen van locatie gaan veranderen. Voor ongeveer 4 procent van de respondenten is een (vrij) hoge waarschijnlijkheid gevonden dat ze als gevolg van een kilometerheffing gaan verhuizen naar een locatie dichterbij hun werk. Daarnaast geeft 11 procent van de respondenten aan dat het (vrij) waarschijnlijk is dat ze op zoek gaan naar ander werk (dichterbij huis).

- Een cordonheffing rond middelgrote en grote steden heeft, in vergelijking tot niet naar plaats gedifferentieerde kilometerheffingen, een hogere waarschijnlijkheid tot herlocatie tot gevolg.

Voor de cordonheffing zijn hogere waarschijnlijkheidspercentages gevonden dan voor de geteste kilometerheffingen: tussen 3 en 5 procent meer respondenten hebben aangegeven dat ze een hoge herlocatiewaarschijnlijkheid hebben.

- Huishoudens die al in (redelijk) sterke mate van plan zijn om binnen twee jaren van locatie te gaan veranderen (dus ook zonder wegbeprijzing) hebben ook vaker aangegeven dat de waarschijnlijkheid dat ze specifiek als gevolg van wegbeprijzing van locatie gaan veranderen groot is.

75 procent van de antwoorden, waarin is aangegeven dat de waarschijnlijkheid groot is om als gevolg van wegbeprijzing van locatie te veranderen, zijn afkomstig van respondenten die in hetzelfde onderzoek te kennen hebben gegeven dat er een grote kans is dat ze sowieso binnen twee jaar gaan verhuizen. Het lijkt er dus op dat wegbeprijzing de uiteindelijke aanleiding kan zijn om van woon- en/of werklocatie te veranderen voor vooral die mensen die al in redelijke mate van plan zijn van locatie te veranderen.

- In hun woonlocatiebeslissing blijken respondenten gevoelig te zijn voor reiskosten (te weten brandstof- en tolkosten).

Respondenten blijken gevoeliger voor veranderingen in reiskosten dan voor even hoge veranderingen in maandelijkse monetaire huur- of hypotheeklasten van de woning. Verder is naar voren gekomen dat reistijd een relatief lage invloed heeft. *Al met al zou hieruit geconcludeerd* *kunnen worden dat respondenten in het algemeen de voorkeur geven aan iets hogere huislasten en langere reistijden om op die manier hoge reiskosten te vermijden.*

Verklarende variabelen voor gedragsveranderingen

- De prijshoogte van de heffing lijkt niet een belangrijke verklarende invloed te hebben op gedragsveranderingen. Hoewel hogere heffingen vaak een grotere verandering in huidige autoritten tot gevolg lijken te hebben, zijn de verschillen dikwijls niet statistisch significant.

Met het oog op verschillen in de waarschijnlijkheid tot herlocatie zijn er (helemaal) geen significante prijshoogte-effecten gevonden. Dit kan deels komen doordat het effect van prijshoogte op herlocatie niet zo uitvoerig is geanalyseerd als het effect op veranderingen in rittenpatroon.

- Belangrijke statistisch significante socio-economische en demografische variabelen voor zowel korte als lange termijn veranderingen zijn inkomen, onkostenvergoeding en het jaarlijkse autokilometrage.

Respondenten met een hoger inkomen en met een hogere reiskostenvergoeding zijn van plan minder huidige autoritten aan te passen en hebben een lagere waarschijnlijkheid tot locatieverandering dan anderen. Het tegengestelde is gevonden voor respondenten die meer dan een gemiddeld aantal autokilometers per jaar rijden: een relatief hogere waarschijnlijkheid tot gedragsverandering. Aanvullend is getest of er een significante relatie is tussen korte en lange termijn gedragsveranderingen. Respondenten die van plan zijn veranderingen door te voeren in hun huidige autoritten blijken ook een hogere waarschijnlijkheid tot locatieverandering te hebben. Het lijkt er dus op dat er 'kostengevoelige' mensen bestaan die op verschillende wijzen beprijzingskosten trachten te reduceren. Desalniettemin, deze bevinding is enigszins in strijd met de verwachting dat mensen eerst korte termijn veranderingen zullen doorvoeren en pas hun lange termijn gedrag aanpassen als de korte termijn veranderingen niet tot een gewenste situatie hebben geleid. Verder onderzoek hieromtrent is daarom aan te bevelen.

Gedragsveranderingen bedrijven (onderzoeksvraag 4)

Gedragsveranderingen van bedrijven uit de industriële sector en de zakelijke dienstverlening zijn onderzocht in hoofdstuk 7 op basis van een stated preference vragenlijst waarin bedrijven een naar tijd gedifferentieerde kilometerheffing voorgelegd hebben gekregen. Het hoofdstuk heeft beoogd de vierde en laatste onderzoeksvraag te beantwoorden. De belangrijkste conclusies zijn als volgt.

- Uit het onderzoek is naar voren gekomen dat bedrijven ontstane baten als gevolg van wegbeprijzing positief waarderen.

Indien de naar tijd gedifferentieerde kilometerheffing ervoor zorgt dat de betrouwbaarheid van reistijd of de reistijd zelf verbetert, dan verbetert ook de perceptie van bereikbaarheid van bedrijven. Als de baten niet expliciet worden aangegeven/geformuleerd dan verwachten bedrijven gemiddeld gezien een licht bereikbaarheidsverlies te ondervinden.

- Het is waarschijnlijker dat bedrijven veranderingen doorvoeren in hun zakelijke ritten dan in hun ritten voor transport van goederen.

Ongeveer 20 procent van de bedrijven is van plan minder zakelijke auto- of vrachtwagenritten te maken; 6 procent denkt minder ritten te maken voor transport van goederen. Mogelijkerwijs is goederentransport van groter (economisch) belang voor bedrijven of is het lastiger om transportritten aan te passen. Niet alle bedrijven zijn echter geneigd om minder ritten te maken. 3 tot 4 procent van de bedrijven heeft aangegeven meer (transport of zakelijke) ritten te maken wanneer de prijsmaatregel wordt ingevoerd. Deze bedrijven verwachten misschien verbeteringen in de reistijd of in de betrouwbaarheid van reistijd.

- Gemiddeld gezien zijn bedrijven als gevolg van wegbeprijzing minder vaak van plan om werknemers te compenseren voor autogerelateerde kosten; andere typen compensaties en flexibilisering worden vaker aangeboden.

Ongeveer 30 procent van de bedrijven heeft aangegeven iets te veranderen in het huidige compensatiebeleid. Vergoedingen gerelateerd aan autokosten (kilometervergoeding, brandstofkosten-compensatie, auto van de zaak) zullen gemiddeld gezien iets minder vaak worden aangeboden. Openbaar vervoer en verhuisvergoedingen zullen vaker worden gegeven; ongeveer 18 procent van de bedrijven is van plan dit te doen. Niettemin, lijken bedrijven er het meeste heil in te zien om werknemers meer flexibiliteit te geven in het kiezen van werktijden en om meer mogelijkheden te bieden om thuis te werken: rond 30 procent van de bedrijven denkt dit te gaan doen.

- Net als voor huishoudens is gebleken dat vooral die bedrijven die al een redelijke kans hebben om binnen nu en 2 jaren van locatie te veranderen (dus zonder beprijzing) als gevolg van wegbeprijzing van locatie gaan veranderen.

Bijna 8 procent van de bedrijven heeft aangegeven dat het waarschijnlijk is dat ze als gevolg van de kilometerheffing een nieuwe vestigingslocatie gaan zoeken. Ruwweg de helft van deze bedrijven is al in redelijke mate geneigd binnen 2 jaren van locatie te veranderen.

Beleidsaanbevelingen

Vanuit beide onderzoekslijnen (bereikbaarheid en gedragseffecten) volgen beleidsaanbevelingen. Deze indeling in twee onderzoekslijnen komt hieronder terug.

Bereikbaarheid: onderzoekslijn 1

- Als het doel van een onderzoek is om wegbeprijzingseffecten vanuit een gecombineerd transport en ruimtelijk perspectief te berekenen dan is het aan te bevelen om geografische bereikbaarheidsindicatoren te gebruiken in plaats van of in aanvulling op economische (bijvoorbeeld welvaartsgebaseerde) of transport indicatoren (bijvoorbeeld reistijdveranderingen).

Het voordeel van geografische bereikbaarheidsindicatoren is dat deze maten gedetailleerd kunnen bepalen welke delen van een studiegebied (bijvoorbeeld een bepaalde regio of zone) in welke mate er op vooruit of achteruit gaan als gevolg van wegbeprijzingsmaatregelen. Het bestuderen van 'ruimtelijke' implicaties kan bijzonder interessant zijn wanneer de effecten van naar plaats gedifferentieerde heffingen moeten worden onderzocht. Deze studie heeft bijvoorbeeld laten zien dat het ruimtelijk bereikbaarheidspatroon (oftewel welke regio's/zones gaan erop vooruit of achteruit) gevoelig is voor de ruimtelijke differentiatie van prijsmaatregelen (dus waar wordt de prijsmaatregel ingevoerd.

- Op basis van dit onderzoek wordt aanbevolen om voor het berekenen van bereikbaarheidseffecten als gevolg van wegbeprijzing gebruik te maken van eenvoudige bereikbaarheidsindicatoren zoals de contour- en de potentiaalmaat.

Deze maten vergen weinig data-invoer en kunnen snel inzicht geven in bereikbaarheidseffecten. Om realistische resultaten te krijgen is het verder goed om in de kostenfunctie rekening the houden met het feit dat verschillende typen mensen reistijd anders waarderen. Een opsplitsing naar inkomensklasse zou het realisme van uitkomsten al in sterke mate kunnen verbeteren.

- Aangezien waarschijnlijk de meerderheid van de automobilisten niet hun huidige autoritten als gevolg van beprijzing gaan aanpassen is het aan te bevelen om vooral 'realistische' bereikbaarheidseffecten te berekenen voor deze groep van autorijders.

Bij het interpreteren van de bereikbaarheidseffecten is het belangrijk om tenminste te onderkennen dat deze methode tot een overschatting van bereikbaarheidsverliezen (of een onderschatting van winsten) leidt voor mensen die *wel* van gedrag veranderen. Inzicht in welke typen mensen van gedrag veranderen kan worden verkregen op basis van stated preference onderzoeken zoals uitgevoerd in dit onderzoek. Verder kan door middel van economische welvaartsanalyses voor deze groep mensen een kwantitatieve inschatting van het verlies in het totale consumentensurplus worden berekend (zie voor verdere uitleg hoofdstuk 2, paragraaf 2.5.3).

Gedragsveranderingen: onderzoekslijn 2

- Als het beleidsdoel is om fileproblemen te verminderen dan lijkt een naar tijd gedifferentieerde kilometerheffing (hogere heffing in de piekperiodes, lagere heffing daarbuiten) effectiever te zijn dan een platte heffing.

Een naar tijdgedifferentieerde kilometerheffing blijkt de meest effectieve maatregel te zijn om huidige autoritten te veranderen voor alle geteste ritmotieven (woon-werk, bezoek en overig). Verder geeft de bereikbaarheidsstudie enige indicatie dat een naar tijd en plaats gedifferentieerde heffing weer effectiever is dan een heffing die alleen naar tijd is gedifferentieerd. Dus vanuit een oogpunt van filereductie verdient een gedifferentieerde heffing (naar tijd en/of plaats) de voorkeur.

- Als effectiviteit van een prijsmaatregel (geoperationaliseerd als het aantal huidige autoritten dat wordt aangepast) het belangrijkste doel is van beleidsmakers, dan zou het goed zijn om opbrengsten uit beprijzingsmaatregelen te gebruiken om bijvoorbeeld inkomstenbelastingen te verlagen. Maar als acceptatie van beprijzing belangrijk is, dan kan het juist beter zijn om opbrengsten te gebruiken om bestaande autobelastingen te verlagen of af te schaffen.

Beprijzing zorgt voor opbrengsten (voor de overheid). Beleidsmakers (of anderen) kunnen deze opbrengsten op verschillende manieren opnieuw investeren. In dit onderzoek is de invloed van twee typen investeringen op gedragsveranderingen onderzocht: (i) het verlagen van inkomstenbelastingen en (ii) de verlaging of afschaffing van huidige bestaande autobelastingen (bijvoorbeeld de BPM en de motorrijtuigenbelasting). Er is gebleken dat wanneer opbrengsten worden gebruikt om huidige vaste lasten van autorijden te verlagen mensen van plan zijn relatief minder autoritten aan te passen dan wanneer de opbrengsten worden aangewend om bijvoorbeeld de inkomstenbelastingen te verlagen. Aan de andere kant zullen opbrengsten die geïnvesteerd worden in het transportsysteem (in plaats van daarbuiten) wel acceptabeler kunnen zijn (zie Ubbels, 2006).

- Vanuit het oogpunt van effectiviteit is het misschien niet goed om 'gevoelige' groepen mensen te compenseren door hun autogerelateerde kosten te verlagen.

Mensen met een lager inkomen zijn meer (en in sterkere mate) geneigd hun rijgedrag en/of locaties als gevolg van wegbeprijzing aan te passen. Er is niet onderzocht in welke mate deze lagere inkomensgroepen meer 'lijden' onder wegbeprijzing. Maar als deze groepen er inderdaad sterker op achteruit gaan dan anderen dan zou de overheid kunnen overwegen om deze mensen extra tegemoet te komen. Deze tegemoetkomingen kunnen worden gefinancierd uit de opbrengsten van wegbeprijzing. Het is aanbevelingswaardig om hun montaire lasten niet op een zodanige manier te verlichten (bijvoorbeeld het verlagen van autokosten) dat de effecten van wegbeprijzing teniet worden gedaan.

- Om de effectiviteit (bestrijding files) van wegbeprijzing te vergroten is het voor de overheid te overwegen om bedrijven (meer) aan te sporen om werknemers vaker niet-autogerelateerde compensaties aan te bieden.

Er is naar voren gekomen dat mensen die een reiskostenvergoeding van hun werkgever krijgen in mindere mate van plan zijn hun huidige gedrag en locaties aan te passen dan mensen die geen vergoeding krijgen. In dit onderzoek hebben bedrijven aangegeven dat ze, ten opzichte van de huidige situatie, werknemers vaker niet autogerelateerde vergoedingen willen aanbieden. Er wordt veelvuldiger gekozen voor het vergoeden van openbaarvervoer kosten en/of het geven van verhuiskostencompensaties. Daarnaast kiezen bedrijven er ook voor om werknemers vaker de mogelijkheid te bieden om (meer) thuis te werken of om flexibeler te kunnen zijn in de keuze van hun werktijden. Deze 'alternatieve' compensaties en geboden flexibiliteit kunnen de intenties van mensen om van gedrag te veranderen doen toenemen.

- Als het succes van een beprijzingsmaatregel wordt opgehangen aan de effectiviteit van een prijsmaatregel dan zou het goed zijn om ook te kijken naar de locatie-effecten.

Deze studie heeft laten zien dat herlocatie-effecten niet verwaarloosbaar zijn. Herlocaties kunnen leiden tot een efficiënter transportsysteem door bijvoorbeeld kortere afstanden en veranderingen in vervoerwijze. Dit kan dan de verkeersituatie gunstig beïnvloeden (bijvoorbeeld minder verliestijd). Verder is gebleken dat mensen gevoelig zijn voor reiskosten in de uiteindelijke locatiebeslissing. Aangezien veel mensen gedurende hun levenscyclus verhuizen kan wegbeprijzing op de langere termijn een (nog) groter effect hebben dan op de korte termijn.

Epilogue - A subjective evaluation of working in this multidisciplinary project

Working in a multidisciplinary project had several important advantages for me. It offered the possibility to learn from the different participants in the project that had different disciplinary backgrounds. These different views often led me to rethink my work, especially with respect to the questions I wanted to ask in the empirical study. Furthermore, the multidisciplinary set up offered the possibility to collect more useful empirical data than would have been possible doing it myself.

The work in the project was not only about doing 'hardcore' research. Sometimes it felt more like a 'normal' job, managing things and negotiating about how the questionnaires should be constructed and which questions had to be incorporated. I learned a lot from doing these other types of tasks as well and they always kept the work interesting. Next to that, I really enjoyed working together and discussing with the other PhD's within the project often struggling with the same kinds of problems.

Nevertheless, there were not only positive experiences. The added value of the multidisciplinary empirical study is undeniable. But the process of collecting data itself was time consuming. As described in chapter 3, the total empirical study was divided into four questionnaires. After each questionnaire was finished, data were collected. The first data became available in the middle of 2004 (two years after I started the PhD position). In October 2005 the data collection phase ended. Since the data I needed was shattered over all four data sets, this implies that a large part of my tasks as student consisted of (part time) data collection. Looking back, my feeling is that this was too long. As a consequence, the time pressure in the last year in which both a large share of the data had to be analyzed and the thesis was supposed to be written was considerably high.

The multidisciplinary set up also made it possible to use results from a traffic assignment model (developed by another participant) to improve the quality of the results of the accessibility sensitivity study in chapter 4. However, the needed adjustments to this traffic model were delayed. After the first modifications (with respect to the route choice and departure time modules) the model could only simulate effects for road pricing measures, which were not differentiated in space. Not earlier than in May 2006 a module came available with which it was also possible to determine traffic effects of spatially differentiated road pricing measures. This in combination with the fact that on a quite average computer[182] a total simulation run (i.e. one price measure, one price level) already took around 50 hours, it was not feasible to simulate everything I intended to do (e.g. evaluate a range of different pricing measures and price levels).

182 The computer used for most simulations has the following characteristics: 512 MB RAM, 2800+ AMD Athlon XP processor.

All in all making up the balance, for me the positive feelings about working in the multidisciplinary project predominate. On the basis of my own experiences I would like to give some general personal advices to all those who intend to work or just started working in a multidisciplinary PhD-project in which data has to be collected together with others:

- *Limit the time needed for data collection*: although the data collected in our project is good and useful even for extended research after the PhD-phase, one should opt for collecting all (or most) of the data at least two years before the PhD-contract ends. In such a situation there is time enough to analyze thoroughly and to write a thesis (possibly on basis of articles).
- *Avoid large interdependencies between participants*, especially when one is at the end of the 'chain': people who have to give the needed input might not feel the urgency of people who have to work with the input, especially not if the provider of the input does not have to work with the final results.
- *It would be good when each PhD in the project is on the same 'time path'* (i.e. starting and ending at more or less the same points in time). In such situations everyone has the same feelings of urgency and as a consequence delays (by some) might be prevented.

Curriculum vitae

Taede Tillema was born on 27 February 1979 in Delfzijl. He started his primary school period at De Noorderkroon in Delfzijl and finished it at De Regenboog in Grijpskerk. In 1997 he received his secondary school diploma from the Willem Lodewijk Gymnasium in Groningen, and started studying Civil Engineering and Management with a specialization in Traffic and Transportation at the University of Twente. Early 2002 he finished his master thesis on the superposition of speed distributions and on the traffic effects of homogenizing travel speeds. In the spring of 2002 he became a PhD student at the Faculty of Geosciences, Utrecht University. Currently he is working as a post-doctorate researcher at the same institute.