

IP-SUNTAN

Innovative Policies for Sustainable UrbaN
TrANsportation

Final Report

With contributions from

Erik Verhoef, Devi Brands, Maria Börjesson, Stefanie Peer, and Stephan Lehner

Contents

- 3 Project leader Erik Verhoef on IP-SUNTAN: 'The outcomes of our research will definitely have impact on policymaking'
- 5 CASE STUDY: Randstad
- 11 CASE STUDY: Stockholm
- 27 CASE STUDY: Vienna
- 36 The IP-SUNTAN research team
- 38 Experimental design
- 45 Behavioural modelling
- 51 Policy conclusions
- 54 In the media

Project leader Erik Verhoef on IP-SUNTAN:

'The outcomes of our research will definitely have impact on policymaking'

IP-SUNTAN (Innovative Policies for Sustainable UrbaN TrANSportation*) is a collaborative research project with universities from Amsterdam, Stockholm, and Vienna.

'We look at innovative measures to deal with urban transportation problems, in particular measures that are based on pricing principles', says project leader Erik Verhoef from Vrije Universiteit Amsterdam. 'The group in Vienna especially looks at new ways of parking to come to a better use of the urban infrastructure. The Swedish research group focuses on refinement of public transport pricing and on the existing congestion charging schemes in the cities of Stockholm and Gothenburg. And in the Netherlands we are working on the theme of tradeable peak permits.'

Excellent research groups

The cooperation between the research groups was very good. 'We had a couple of project meetings, which were very productive and informal at the same time. Vienna and Stockholm are excellent research groups, we speak the same language, we get excited over the same sort of policy issues, and over the same sort of policy instruments that we are studying. It is therefore very easy for us to reflect upon one another's work, and to give valuable advices in all directions. All partners brought their own expertise, leading to cross-fertilization.'



Worldwide relevance

What is IP-SUNTAN's relevance to society? 'Dealing with externalities is one of the main challenges in urban, transport and environmental policies. Externalities refer to all types of market values that lead to overconsumption of certain types of goods. Examples are CO₂

emissions, emissions that inflict on local and environmental quality in cities, but also traffic safety, traffic congestion, noise annoyance of urban transport. These difficulties are not unique for the cities I mentioned, but are ubiquitous across the world.'

Synergy with other research projects

Is there a relationship with other research projects? 'IP-SUNTAN is strongly related to U-SMILE**, a Dutch SURF project which specifically looks at the development and testing of tradeable permit systems. That means that we have a nice group of PhD students and postdocs working on the same field. We can combine modelling, empirical research, design, evaluation, which would be too much for just a single PhD student. Also BREATHE*** is – although less strongly – related to IP-SUNTAN: It also deals with environmental challenges in urban transportation. We try to obtain synergy as much as possible.'

Follow-up

'The outcomes of our research will definitely have impact on policymaking', says Verhoef. 'There is a lot of interest in the research we are doing. Several projects are using the concept that we have developed. Seven different experiments are in preparation. So I think we will see a spin-off of what we have been doing within let's say two years. However, this is a very volatile field. So, unfortunately, I cannot give any guarantees. As researchers we are not in the seat of the policy makers. There can always be political issues.'

*The project website can be found at <https://sbe.vu.nl/ip-suntan>.

**Urban Smart Measures and Incentives for quality of Life Enhancement, see for more information <https://sbe.vu.nl/u-smile>.

***Building Resilient Economic Agglomerations addressing Transportation and Health Effects: Urban form, location choice and transport solutions for high air quality and low-carbon cities, see for more information <https://sbe.vu.nl/breathe>.

Case study:

Randstad



Tradable mobility permits: theoretical ingenuity or promising rush hour policy?

Accessibility and sustainability are important conditions for vital and resilient cities, but are under pressure as a result of increasing clustering of companies and households. This clustering creates multiple challenges such as congestion, reduced air quality and scarcity of space for parking. These challenges have in common that effective solutions require behavioural change in addition to technological innovation. Many policy makers and researchers have been looking into how to actualise such solutions for quite some time, and often agree that there is no golden bullet solution that solves all these challenges. A successful policy is likely to be a combination of relevant measures. Multiple reasons exist to claim that smart prices should be an important component of such a combination of measures. Smart prices have the potential to be very effective. Experience in multiple countries confirms that this is the case for congestion charges, as well as for rewards to avoid the rush hour. Furthermore, such prices can strengthen the effectiveness of other measures, such as increasing the flexibility of working hours. This

flexibility will be more effective if firms and employees that successfully change to travelling outside the rush hour are rewarded for doing so by lower prices.

Pricing or rewarding...

The multiple advantages of smart pricing help to explain why much attention has been focussed on making vehicle taxes vary. Nevertheless, many of these efforts have not succeeded. Although there are many reasons - political and social - for opposing pricing measures, an important part of resistance comes from the simple fact that these measures are usually seen as an additional tax, on top of existing taxes that are often already perceived as high. This partly explains the success of rewarding measures, such as *Spitsmijden* projects, where the financial incentive is positive: a reward for avoiding rush hour. These rewarding measures can count on broader support, certainly among road users, and are highly effective (avoidance rates between 40% and 50% for participants are no exception). However, they create new problems. The limited budgets for rewards are an important example of this. This ensures that, so far, applications have always been local and temporary, often around road works.

... or a budget neutral hybrid?

Against this background, the IP-SUNTAN project focuses on developing, testing and evaluating smart budget neutral measures to influence mobility behaviour. The measures to be developed and researched are smart because they form an innovative combination of positive and negative financial incentives, without the disadvantage of pricing (a lack of public support) and the disadvantages of rewarding (pressure on government budgets and a possible increase in demand). The measures are also smart because of their innovative character in terms of technology, both from a conceptual point of view (e.g. tradable mobility permits), but also, for example, by linking automated vehicle recognition to a virtual market. The project brings together research groups, local authorities and case studies from Amsterdam, Rotterdam, Stockholm, Gothenburg and Vienna.

Tradable permits

Tradable rush hour permits are an important form of budget-neutral pricing measures. The basic idea is simple: for every rush hour trip that is made on a certain road or in a certain area a permit is used. Participants are initially allocated a number of permits. If they succeed in reducing the number of rush hour trips more than the number of permits they have received, they can sell permits. If they fail to do so, they will have to buy additional permits. For a rush hour driver who goes from 5 to 4 morning rush hours per week and who has received 4 permits as a result of a permit policy, road pricing would mean that he pays a toll 4 mornings; rewarding rush hour avoidance means that he receives a reward for 1 morning per week, and tradable permits mean that the driver does not gain or lose money. The system is budget-neutral in the sense that no money flows from road users to the road administrator (as in the case of road pricing) or vice versa (as in the case of rewards), but only between road users.

In theory, such a system should have a similar degree of effectiveness as pricing policy and rewards, but in practice this depends partly on whether road users understand the tradable permit system as intended. Whether this is the case has been investigated in a first experiment within the IP-SUNTAN project, the so-called lab-in-the-field experiment.

Lab-in-the-field experiment

The aim of the lab-in-the-field experiment was to investigate how trade in mobility permits works in practice. A virtual experiment has been conducted in which there are no effects on actual mobility behaviour. First of all, we looked at trading behaviour: do the participants understand the concept of tradable permits as intended? In addition, we looked at the supply and demand for mobility permits, and in particular the price dynamics in the market for permits. The experiment took place in December 2017 and consisted of two weeks. In the experiment, participants had to make a virtual parking choice on the mobile website every working day via their smartphone or computer.

Parking choice

To pay for a parking spot, participants could choose between (1) paying a regular parking fee (from their personal budget), or (2) using a tradable parking permit. The parking fee is the given, fixed price of parking for a whole day. This fee varied over the different working days, in an order that differed between participants. At the beginning of the week it was clear which daily parking fee would apply on which day. Parking permits, on the other hand, could be sold and bought at any time at a price that changed depending on the trading behaviour of the participants.

Motivation

Participants received a starting budget and a number of tradable parking permits at the start of each of the two weeks. In order to motivate participants to trade and choose as seriously and smartly as possible, the remainder of the budget of participants at the end of each of the weeks was transferred to them in real money.

Price dynamics

The design of the experiment was such that the equilibrium price of the tradable permits could take any value between €2 and €3: on average participants had 3 permits per week that they could use to avoid paying parking fees of €3, €4 and €5. They could then use the budget for the parking fees of €1 and €2. In both weeks, the price of permits moved largely between €2 and €3, with the price adjusting relatively quickly when getting outside of this range. Overall, participants acted as expected, and the market for permits functioned as intended.

Budgets of participants at the end of the week

If participants acted completely rationally and the price of permits would not change, each participant would have €10 left at the end of a week. The average final budgets were €7.38 in the first week and €8.40 in the second. Participants who made a parking choice every working day ended up with an average budget of €10.15 in the first week and €10.31 in the second week. This is a second indication that participants traded and choose successfully and in accordance with how the market design is intended.

Rational choices

If the graphs in Figure 2 show that by far the largest part of the choices made in both weeks was rational (92.7% in week 1 and 93.5% in week 2); that is, in accordance with the intended incentive to maximise the final budget. In addition, most irrational choices were made in situations where they had relatively little influence on personal budgets (at a parking fee of €2 or €3). These results further indicate that participants behaved in accordance with the incentives given in the experimental setup. Tradable permits were used as intended: to be used when they are most beneficial (in the experiment: when using the permit saves the most compared to paying the parking fee), and to be traded if that is more beneficial than using it.

	Week 1	Week 2
Mean	€ 7.38	€ 8.40
Maximum	€12.34	€13.67
Earning participants	73	60

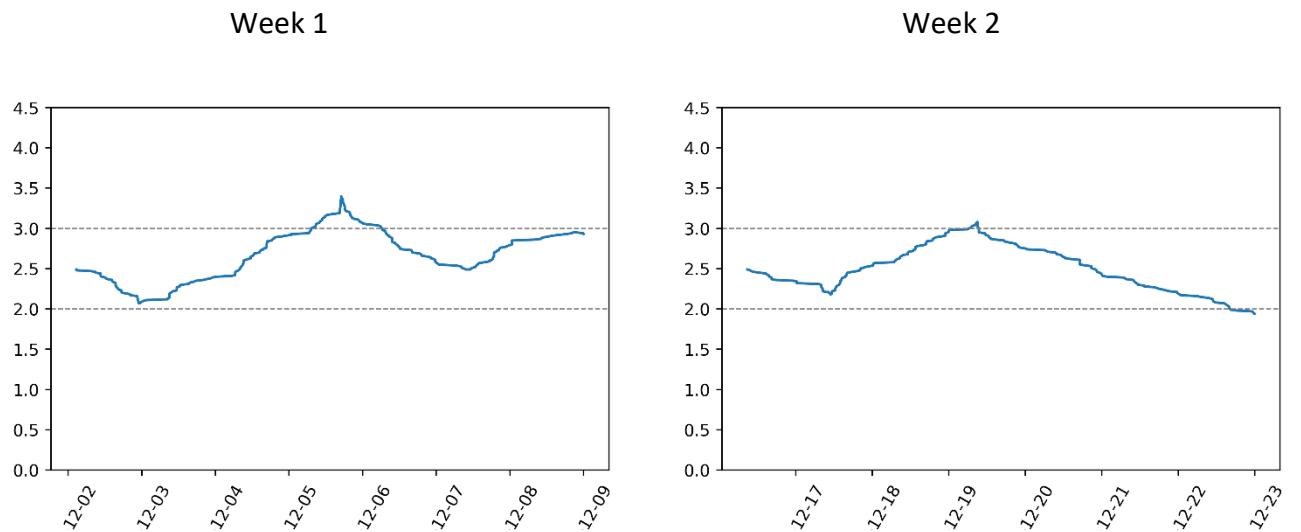


Figure 1. Price dynamics of parking permits (in euros)

Survey results

Most participants did not find it difficult to make a good parking choice, as can be seen in the left-hand graph of Figure 3. Most participants also did not find it difficult to determine the best trading strategy, although there were more participants who had some difficulty with this (see the right-hand graph of Figure 3). This is in line with what may be expected: to make the rational parking choice, only the daily parking fee needs to be compared with the current price of tradable permits. However, when making decisions to buy or sell permits, expectations about the future price development and the parking choices that still need to be made also play a role.

Finally, Figure 4 shows that almost half (about 45%) of the participants, after two weeks of experience, agree with the proposition that tradable parking permits are an instrument that could

also sometimes be a good alternative to paid parking in practice. The number of participants who disagree with this statement is half as big (about 23% of the total); about one-third of participants answer neutrally.

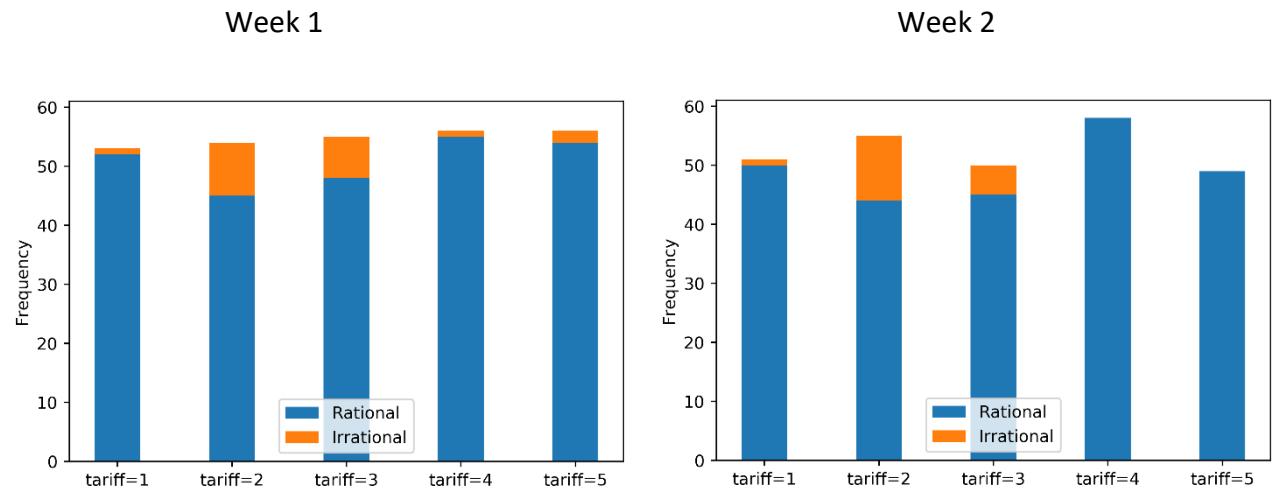


Figure 2. Rational choices per daily fee

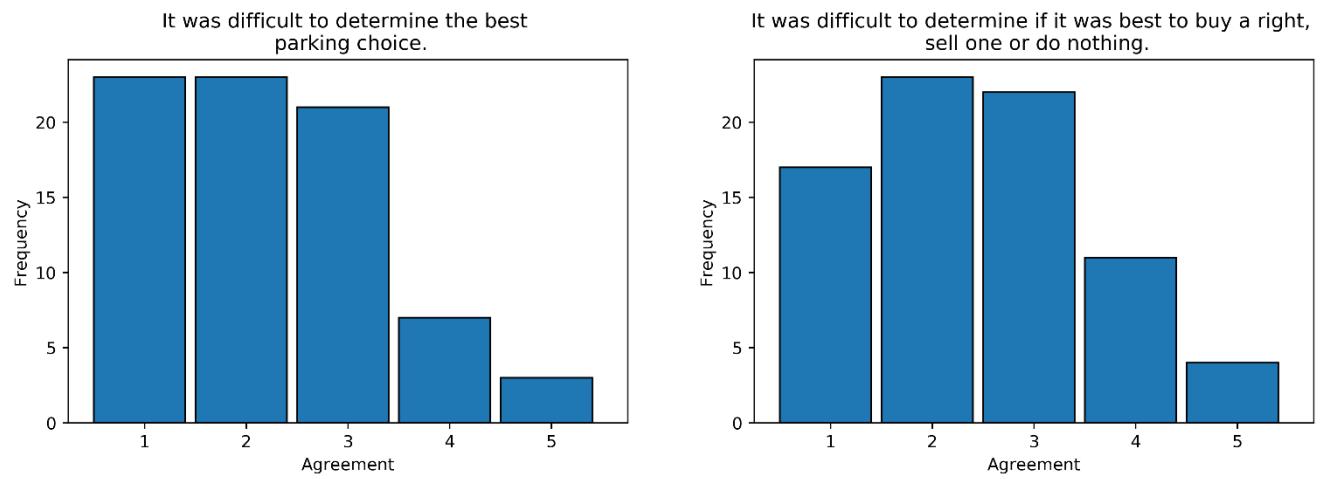


Figure 3. Perception of participant with respect to difficulty

Tradable parking rights could in reality sometimes be a good alternative for paid parking.

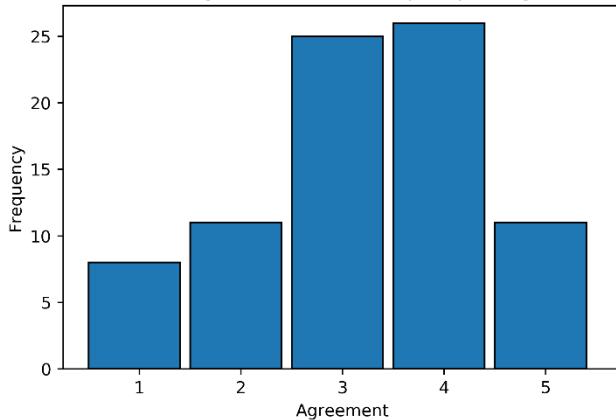


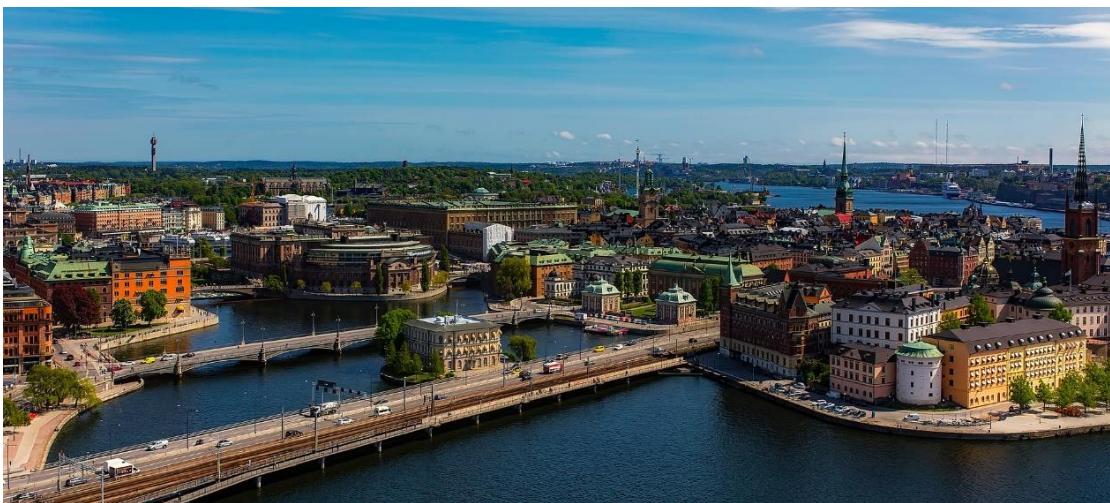
Figure 4. Application of tradable parking permits

Conclusion

Although at first sight tradable mobility permits appear to be a more complex instrument than direct rewarding or pricing, this experiment shows that they certainly constitute an interesting option that justifies further research. The permits are used and traded in accordance with their intended purpose, while the permit market is indeed achieving the intended equilibrium, both in terms of prices and quantities. The advantage of this is that the instrument, unlike taxes or rewards, is budget neutral at an aggregate level: there is no net cash flow between road administrator and road users.

Case study:

Stockholm



Contemporary cities face immense challenges with traffic congestion, crowding in the public transport system, and local air pollution (not the least after the Diesel gate). The increasing congestion and air quality problems in metropolitan areas calls for a range of policy instruments. With early metro investments in the 1950's resulting in a public transport share of 80% in central Stockholm, and congestion charges in 2006, Stockholm has since long a tradition of being progressive in implementing and innovating such policy tools. In this project we have analyzed the behavioural effects, as well as social gains and losses of four policy instruments introduced or considered for the city of Stockholm: congestion charges, introduction of parking charges in the regional center outside the inner city, the introduction of low emission zones, and reducing crowding in the public transport system. The advantage of analyzing behavioral responses to such policies in Stockholm is the valuable, unique and accurate data available from the Stockholm congestion charging system. These data include traffic flows, behavioural responses to policy change and types of vehicles entering the city. In the following, we will briefly describe the main conclusions and policy recommendations generated from the four case studies.

Long run effects of the congestion charges and behavioural responses to charge increase

Introduction

Although congestion charges were considered an efficient remedy to congestion problems for decades, the implementation was held back by a lack of public and political support in cities around the globe. Several researchers noted that a central reason for this scepticism is the belief that congestion charges will not “work” – particularly not in the long run. Currently, two Swedish cities, Stockholm and Gothenburg, have implemented congestion charges in full scale, providing unique data sources regarding the behavioural response. The Stockholm congestion charging system was introduced as a trial 2006 and altered in 2016; the Gothenburg system was introduced in 2013 and altered 2015. This study performs an evaluation of long-term traffic effects (traffic volumes and travel time by automobile and public transport), transferability of experience and results (regarding traffic effects and public opinion), and long-term charging system costs and public support. The study also compares the price elasticities (price change effect on traffic volume) of an increase in charging levels with those observed when the charges were first introduced. This indicates the possible benefits with of dynamic charging levels. Evidence from London and Singapore indicate small demand effects in response to adjustments in pricing levels. This result was confirmed by the present study.

The Stockholm congestion charge system, introduced in January 2006 as a six-month trial, was designed as a toll cordon surrounding the inner city (dotted line in Figure 1). Charges are time-dependent and levied on weekdays between 6:30-18:30. Vehicles are charged when crossing the cordon in both directions. Following the trial, a referendum resulting in a majority voting in favour of the charges and the system was permanently reintroduced in 2007. Since January 2016, a charge has also been levied on the Essinge bypass (E4/E20), a heavily congested highway west of Stockholm city centre (depicted in green between points 6 and 10 in Figure 1). Stockholm is built on islands, and the Essinge bypass is the only road between south and north, outside of the inner city. There are several bottlenecks on the Essinge bypass and it operates close to capacity for much of the day. It was excluded from the initial 2006 charging system because of political concerns, although increasing congestion on the bypass and growing public support for the congestion-charging scheme led to the implementation of the charges on the bypass a decade later.

From 2006 to 2015, the charge ranged between 1 EUR and 2 EUR per passage, however in January 2016 the charging levels were increased, ranging from 1.1 EUR to 3.5 EUR per passage.¹ This equates to a 75% price increase in the peak and a 10% price increase in the off-peak. The maximum charge for one day also increased, from 6 EUR to 10 EUR. The charge on the Essinge bypass (point 9 in Figure 1), is 3.0 EUR, which is slightly lower than the charge on the toll cordon to enter the city centre during peak hour.

To be able to analyse the behavioural effect and the welfare effect we gained access to and analysed the traffic volume data collected by the charging system, sorted by time of day and different types of traffic (trucks, company cars and private passenger cars). These are novel data, because in previous analyses of the original systems, researchers had no access to data segmented by vehicle type due to legal and integrity issues. The detailed data allows an increasingly thorough analysis of the effects on various types of traffic (private cars, company cars and trucks). We also collected data on travel time changes in response to the increased charges by using floating car² measurements on the arterials of Stockholm.

¹ Throughout this report, we use the conversion rate of 10 SEK ≈ 1 EUR.

² Floating car data are derived from vehicles that are being driven regularly and systematically over many days collecting traffic and parking data.

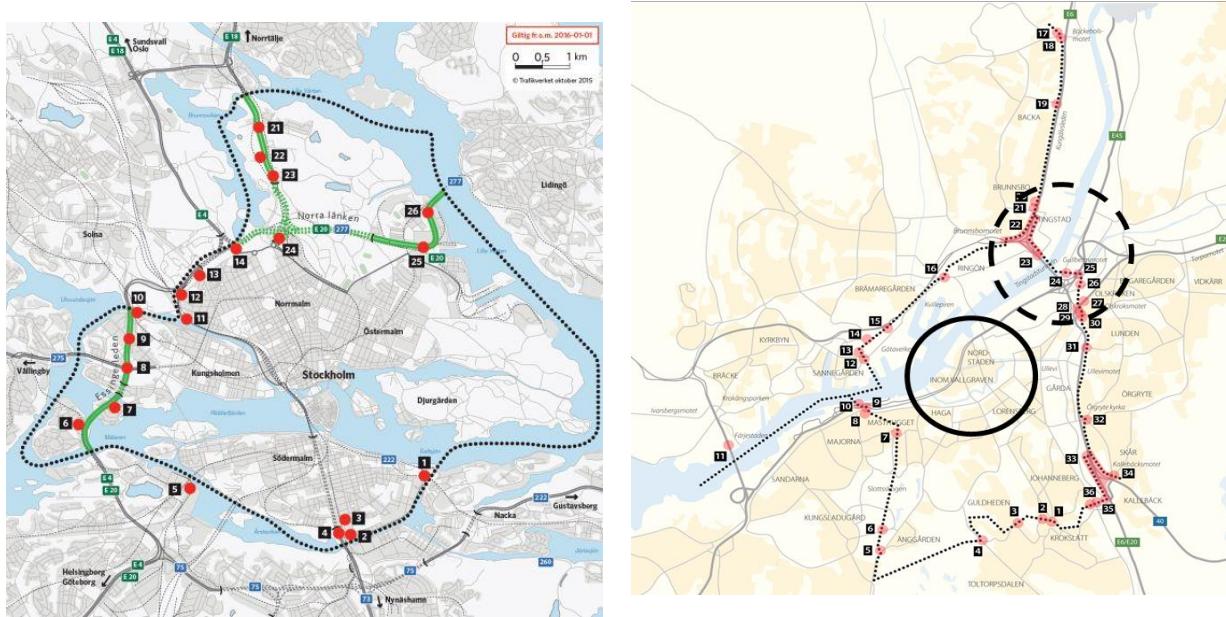


Figure 1. The Stockholm (left) and Gothenburg (right) congestion charging systems. The toll cordons are depicted with dotted lines. In Stockholm, the bottlenecks are located on the cordon, to the entrance of the inner city and on the bypasses (green line). In Gothenburg, the highway hub where the main bottlenecks are located is depicted with a dashed circle and the inner city with a solid circle.

Table 1. Charged amount (EUR) in Stockholm and Gothenburg depending on time of day before and after the charge increases.

	Stockholm			Gothenburg	
	Inner-city cordon 2006	Inner-city cordon 2016	Essinge bypass (E4/E20) 2016	Cordon 2013	Cordon 2015
06:00–6:29	0	0	0	0.8	0.9
06:30–6:59	1.0	1.5	1.5	1.3	1.6
07:00–7:29	1.5	2.5	2.2	1.8	2.2
07:30–8:29	2.0	3.5	3.0	1.3	1.6
08:30–8:59	1.5	2.5	2.2	0.8	0.9
09:00–9:29	1.0	1.5	1.5	0.8	0.9
09:30–14:59	1.0	1.1	1.1	0.8	0.9
15:00–15:29	1.0	1.5	1.5	1.3	1.6
15:30–15:59	1.5	2.5	2.2	1.8	2.2
16:00–16:59	2.0	3.5	3.0	1.8	2.2
17:00–17:29	2.0	3.5	3.0	1.8	2.2
17:30–17:59	1.5	2.5	2.2	1.3	1.6
18:00–18:29	1.0	1.5	1.5	0.8	0.9
18:30–18:59	0	0	0	0	0

Analysis

Over the past dozen years in Stockholm, traffic volumes across the cordon have increased. This might suggest that the price-elasticity of traffic has decreased over time. However, that interpretation ignores two factors: first, the impact of external factors such as population growth,

and second, the attenuation of the charge level in real terms due to inflation (note that as time passes, it becomes increasingly difficult to separate the effects of the congestion charges from other external factors.) The arc elasticities of automobile travel are calculated as

$$E_{x \rightarrow y} = \frac{\text{LOG}(D_y) - \text{LOG}(D_x)}{\text{LOG}(P_y) - \text{LOG}(P_x)},$$

Table 2 shows how the input variables in this equation (D and P for the base year 2005 and 2006-2014) are computed to derive the price elasticity for Stockholm for the years 2006-2014. According to a time series mode for Stockholm, the external factors explaining the trend in the traffic across the cordon in Stockholm are employment and relative car ownership in the county, as well as fuel price (several other variables were also tested but added no explanatory power, or significance). The total effect of these factors on the traffic volume across the cordon is shown in the first row in Table 2. The third row shows the reduction of traffic across the cordon, adjusted for external factors to the 2005 level. This row therefore shows estimates of what the traffic volume would have been had the external factors remained constant since 2005, when the congestion charge was put in place. Alternative fuel cars were exempt until 2011. In 2006 during the trial taxis (approximately 8% of the vehicles across the cordon) were also exempt from the charges. However, since the charges were permanently reintroduced in 2007, taxis have been charged. For this reason, the share of exempt vehicles dropped from 28% in 2006. At the same time, the share of alternative fuel cars grew rapidly, so that in 2011, 24% of the vehicles were still exempt. In 2011 the exemption for alternative fuel vehicles was abolished and in 2015 the exemption for traffic to and from the island of Lidingö³. Now, the exemptions are only 5%.⁴ The fourth row of Table 2 shows the reduction of non-exempt traffic, adjusted for external factors to the 2005 level. We compute the elasticity for non-exempt vehicles only.

To calculate the average trip costs excluding the congestion charge, we assume the driving cost per kilometre used by the Swedish tax authorities, 0.15 EUR/km in 2006. According to a two-wave travel survey in 2004 and 2006, the average trip length for trips crossing the cordon to/from Stockholm inner city remained constant at 17 km in travel surveys in 2004 and 2006. The congestion charge is adjusted for inflation and tax deductibility for company cars. Using the trip cost and traffic volume of 2005 as initial state, the price elasticity of the traffic volume across the cordon is computed. Table 2 shows that the elasticity for the non-exempt traffic increased steadily over the years after the introduction, from -0.87 at introduction in 2006 to -1.24 in 2014. The adjusted (for external factors) traffic volumes of non-exempt private traffic, excluding company cars and taxis (31% of the traffic across the cordon in 2006), and light and heavy trucks (18% across the cordon in 2006), are shown further down in Table 2. The calculations for private traffic result in the elasticity -1.57 in 2006, increasing to -2.49 in 2014.

³ Until 2015 approximately 10% of vehicles were exempt due to a special rule for traffic to and from the island of Lidingö, which before 2016 could not access the national road network without travelling through the area surrounded by the cordon. The rule stated that if traffic to and from the island of Lidingö left the cordoned area within one hour from the time they entered they were exempt from the charges. [This info about Lidingo, while important, should have been introduced earlier, when the exemption was mentioned but only in general terms.]

⁴ Hence, Stockholm is different from London in terms on exemptions. In London taxis including Uber are exempt from the congestion charge and growth in this business has therefore eroded the revenue from the charge in London (The Economist Aug 3rd 2017, How and why road-pricing will happen).

Table 2. Elasticities of congestion charging in Stockholm for the years 2006-2014. Price level 2006. Years 2005-2011 are based on data used by Börjesson et al., 2012.

	2005 (without)	2006 (with)	2007 (with)	2008 (with)	2009 (with)	2010 (with)	2011 (with)	2012 (with)	2013 (with)	2014 (with)
Total effect on traffic volume from external factors	0%	0.51%	2.70%	3.15%	4.61%	3.59%	3.93%	3.50%	6.13%	8.51%
Real average trip cost excluding the charge (EUR)	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55	2.55
<i>Charged hours: total</i>										
Traffic volume across the cordon adjusted to 2005 levels wrt external factors (veh/h)	37 291	29 324	29 514	29 601	29 162	29 280	28 526	28 128	27 439	27 283
Non-exempt traffic volume across the cordon adjusted to 2005 levels wrt external factors (veh/h)	30 021	21 114	21 783	21 614	20 839	21 153	20 721	20 843	20 697	20 550
Real average charge (EUR)	0	1.28	1.06	1.04	1.06	1.03	0.99	0.94	0.92	0.91
<i>Elasticity charged hours</i>		-0.87	-0.93	-0.96	-1.05	-1.03	-1.13	-1.16	-1.21	-1.24
<i>Charged hours: private</i>										
Traffic volume across the cordon adjusted to 2005 levels with respect to external factors (vehicle/h) private	25 140	13 287	12 875	12 458	11 082	11 678	11 368	11 906	11 956	11 747
Real average charge private (EUR)		1.28	1.06	1.04	1.06	1.03	0.99	0.94	0.92	0.91
Elasticity charged hours private		-1.57	-1.93	-2.06	-2.36	-2.26	-2.43	-2.38	-2.42	-2.49

Table 3 shows how the corresponding elasticities for Gothenburg are calculated for the years 2013-2015. There is no time series model to control for external factors for Gothenburg (like the one used for Stockholm). For this reason, we assume that the traffic increases due to other factors than congestion charges equals the national growth in car traffic. The first row of

Table 3 shows how the national car traffic growth increased, most of which can be explained by GDP growth and a declining fuel price (Bastian et al., 2016; Bastian and Börjesson, 2015). The second row shows the trip cost excluding the congestion charge. For Gothenburg, the average trip length for cars crossing the cordon is 15 km, taken from the two-wave travel survey conducted before and after the introduction of charges (March 2012 and March 2013) (City of Gothenburg, 2013). The average trip length did not change significantly between the two survey waves. The Swedish tax authorities' driving cost was 0.185 EUR/km in 2013. As for Stockholm, we also compute the elasticities for private trips only, i.e. passenger cars that are not owned by a legal person (non-business-owned) and taxis (which together has remained stable at around 21% since 2013) or light and heavy trucks (which has remained stable at around 22% since 2013).

Table 3. Elasticities of congestion charging in Gothenburg for the years 2013-2015. Inflation has been near zero during 2013-2015. Price level 2012.

	2012 (without)	2013 (with)	2014 (with)	2015 (with)
Total effect on traffic volume from external factors	-	-0.10%	2.20%	3.42%
Real average trip cost excluding the charge (EUR)	2.78	2.78	2.78	2.78
<i>Charged hours: total</i>				
Traffic volume across the cordon adjusted to 2005 levels wrt external factors (veh/h)	52 597	46 855	47 581	47 525
Real average charge (EUR)	-	0.51	0.50	0.59
Elasticity charged hours	-	-0.69	-0.60	-0.52
<i>Charged hours: private</i>				
Traffic volume across the cordon adjusted to 2005 levels wrt external factors (veh/h)	29 717	26 473	27 169	26 852
Real average charge private (EUR)	-	0.59	0.58	0.69
Elasticity charged hours private	-	-1.18	-1.01	-0.85

In summary, the elasticity for the total traffic volume across the cordon in Gothenburg was -0.69 in 2013. This elasticity is slightly lower than the one observed in Stockholm in the first year, -0.87. There are also different elasticity trends in the two cities. Whereas the Stockholm elasticity has steadily increased over the years from -0.87 at its introduction, the Gothenburg charging elasticity has declined from -0.69 in 2013 to -0.52 in 2015. The 2015 elasticity for Gothenburg is not directly comparable with the previous elasticities and the Stockholm elasticities up to 2011, because of the increases in the charging levels in January 2015. However, the 2014 elasticity is still lower than that observed for 2013.

The discrepancy between Stockholm and Gothenburg regarding the elasticity at the introduction, and the direction of the trends in the elasticities might be driven by differences in city structures and transport systems. Since Gothenburg is smaller and less dense than Stockholm, and most workplaces are located outside of the city centre, the public transport share is lower in Gothenburg. It means fewer ways to adapt in the long run.

However, one similarity between the cities is the seemingly higher price-elasticity in the off-peak than in the peak (largely a result of off-peak trips paying the peak charge in the other direction). In the peak, we observe the elasticities -0.67 and -0.53, in Gothenburg and Stockholm, respectively (and in off-peak -1.13 and -0.93). This means that the effect of the charges per euro is larger in the off-peak to the peak.

In 2015, the Gothenburg charging levels were increased by 22% (from 1.8 to 2.2 EUR) in the peak, but marginally in the off-peak (from 0.8 to 0.9 EUR). In 2016, the Stockholm peak charge was increased by 75% (from 2 to 3.5 EUR) but the off-peak charge was increased only marginally (from 1 to 1.1 EUR). In Gothenburg the peak elasticity was -0.16 when the charge was increased, compared to -0.53 at first introduction. In Stockholm, the peak elasticity was -0.28 when the charge was increased, compared to -0.67 at first introduction. Hence, in Stockholm and Gothenburg, the elasticity of the increase of the charging levels was substantially lower than when the systems were first introduced. The transaction cost for paying the charge is small. Hence, the most likely reason for the lower price-elasticity is that the most price-sensitive car trips are already priced off the road at its first introduction and are no longer being taken when charges were later increased.

Trends in the public opinion and effects of charge increases

The main obstacle for introducing congestion pricing is often public resistance. However, both Stockholm and Gothenburg, and several other cities, have reported that the public support increased shortly after the congestion charges were introduced. Other examples include London and Milan. Several explanations for this phenomenon have been hypothesized. Based on an extensive two-wave survey of public attitudes before/after the introduction of congestion charges in Gothenburg, Börjesson et al. (2014) estimated models where respondents' attitudes to congestion charges are explained by variables such as expected toll payments, value of time, socioeconomic factors, beliefs about effects, and attitudes to related issues such as environment, equity, taxation, government and pricing policies in general. They conclude that status quo bias is the main contributing factor to the increased support in Gothenburg. Contrary to what is often assumed, "larger benefits than expected" does not play any role for the change in support in Gothenburg (the respondents had the same belief in the effect in the before and in the after wave of the survey).

However, the long-term trends in public support in the two Swedish cities indicates a longer story. Figure 2 shows how public support for the charges has developed in Stockholm. In 2004, over 45% of the citizens of the city of Stockholm stated that they would vote in favour of congestion charges in a referendum. The support fell, however, as the introduction approached and just before the introduction of the charges opinions in favour had fallen below 40%. Once the charges were introduced, the support increased again and in the referendum in the autumn of 2006, 53% of the citizens of the city of Stockholm voted to keep the charges (excluding blank votes). Up until 2013, the support for the charges gradually increased to over 70%.

When the charges were revised in 2016 the support for the charges dropped to 60%, which is almost down to the 2006 level. The decline in support is probably an effect of the extension of the system to the Essinge bypass, the substantial peak charge increase, or the small effect it had on travel times (the effects are so small that the travellers cannot have noticed them, except for some segments on the bypass). The use of and focus on the revenues for infrastructure with low value for money that few citizens will benefit from, framing the charges as a tax instrument, might also contribute to the decline in support.⁵

⁵ The revenue generated from the extensions of the charging system and the increased charging levels are earmarked for co-financing of new metro investments (making up 46% of the total cost), leveraged with funding from the municipalities of the Stockholm region (27%), Stockholm County (3%) and the national government (24%) (The Stockholm Agreement, 2013).

In Gothenburg, just over 30% supported congestion charges in 2011, and this support declined to 27% just before the charges were introduced (See Figure 3). Just as in Stockholm, support increased after the introduction, however, the referendum in September 2014 resulted in 55% voting for abolishing the charges (the referendum was only consulting as so was not enforced by the decision-makers because the revenue is used for funding a large infrastructure investment package⁶). In a poll in the autumn of 2014, just after the referendum, 51% stated that they supported the charges.⁷ After the increases in the charging levels, support for the charges fell (as in Stockholm), and since then it has continued to decline.

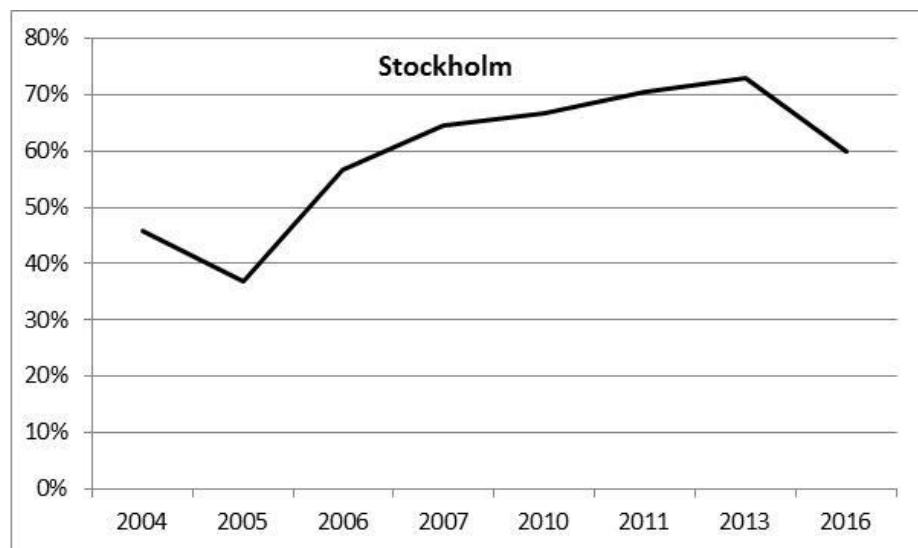


Figure 2. The share of respondents who stated they would support the congestion charges in a referendum. The question is formulated as: "How would you vote in a referendum about the Stockholm congestion charges?"

Conclusion and policy advice

It has now been nearly 13 years since congestion charges were introduced in Stockholm. They were extremely controversial ten years ago but have become increasingly accepted among decision-makers in Sweden. Many view the charges as a policy to reduce congestion, but also to

⁶ In 2007, Stockholm received a major transport road investment package, 50% funded by the charge revenue and 50% by the national government and the revenue were earmarked for a new bypass. It led the decision-makers in the Gothenburg region to seek a similar deal, resulting in a broad political coalition in the Gothenburg City Council to support the “West Swedish package”, partly funded by congestion charges (October 28, 2009). The largest investment in this package is the West Link (2.0 billion EUR), which is an 8-km-long rail link including a 6-km-long tunnel under central Gothenburg with BCR 0.45 (Mellin et al., 2011). The co-financing of the West Swedish package is the reason behind the increases in the charging levels in Gothenburg 2015 (it was not justified by congestion).

⁷ It is unclear why the support in the referendum in autumn 2014 was lower than in the poll just after. One possibility is that the 22% of the respondents in the poll that were undecided had a stronger tendency to vote against. Another possibility is that citizens that are more positive to the charges have a higher response rate in the poll.

combat climate change, to finance new infrastructure, and to reduce local air pollution and noise. Key questions for the coming decade are whether the charging system should be further extended, and which other cities can learn from the Swedish experience.

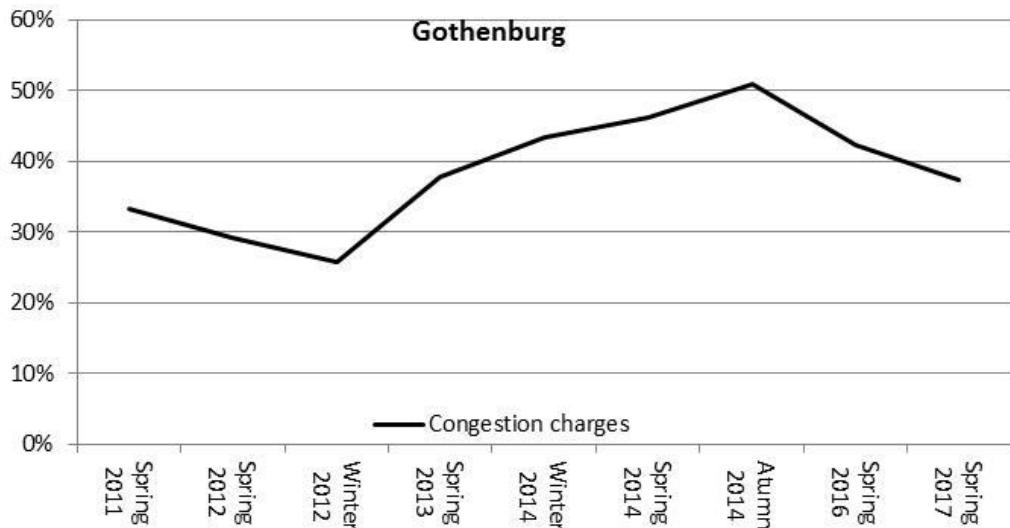


Figure 3. Share of respondents who state that they are positive or very positive to the congestion charges (solid line) and the West Link (dotted line). The question is formulated as: "How positive or negative are you to the package as a whole?", "Congestion Charging - part of the financing of the other parts of the package?" and "the West Link?" (respectively).

The congestion charges have in many ways become a success story. They were initially effective in reducing traffic volumes and are socially beneficial in both Stockholm and Gothenburg. The automatic number plate recognition (ANPR) system technology has proven to be very robust. Moreover, the operating costs of the systems have declined substantially over time. There also seem to be a strong case for reducing not only congestion but also health-damaging emissions in large metropolitan areas. Hence extending the system by a differentiation of the charging levels such that vehicles emitting more health-damaging pollutants pay higher charges might be a good idea.

However, whereas the price elasticity has increased over time in Stockholm, it is declining in Gothenburg. The discrepancy between Stockholm and Gothenburg regarding the direction of the trends in the elasticities might be an effect of differences in city structures and transport systems. Gothenburg is much smaller and less dense compared to Stockholm, with most workplaces located outside the city centre. For these reasons Gothenburg has substantially lower public transport shares and the congestion is located on the highway hubs rather than around the city centre. This means fewer ways to adapt to the charges in the long-term. Some drivers might even have tried public transport but switched back to a car. Whether this experience is transferable to other cities is difficult to know but is at least a warning.

The behavioural effect of extensions and further increases in the charging levels is diminishing. This implies that the sum of money that is redistributed in relation to the welfare gain of a further increase in the charging levels or extension of the system is larger than when the systems were first introduced. The lower price elasticities observed after the increase in charging levels in Stockholm and Gothenburg also indicate that dynamic price adjustments are not effective.

Moreover, public support is sensitive to system revision. The gradual increase in public support after the charges were introduced and before it was revised, and the positive referendum result, are perhaps the most surprising and encouraging lessons of the Stockholm congestion charges. However, after the system revision in 2016 the public support fell for the first time. The story of Gothenburg also underscores that public support should by no means be taken for granted even after introduction of the charges: the decision-makers have not been able to build long-term stable public support for the charges, possibly due to lower congestion levels and higher car dependence.

The effects of Low Emissions Zones: costs and benefits

Background

Since the diesel gate scandal in 2015, many cities are considering introducing low emission zones, or extending existing low emission zones, banning dirty passenger cars or trucks to reduce health-damaging emissions. In March 2018, the Swedish government passed new legislation allowing city governments to introduce Low Emission Zones (LEZ). At the same time, the city of Stockholm also proposed introducing a LEZ, banning light petrol vehicles (mainly cars and light trucks) below Euro 5 emission standard and light diesel vehicles below Euro 6 standard by 2022. The geographical design of the zone is still under discussion, but the second-hand market for diesel and petrol cars reacted as the City Government passed the new legislation.

The aim of this study is therefore to set up and define a methodology for computing the social benefits as well as the cost of LEZ. We apply the evaluation framework to a suggested LEZ in Stockholm. Stockholm provides a unique opportunity of computing these costs due to the micro data available from the congestion charging system, in terms of visiting frequencies to the inner city by vehicles type (fuel type, year model Euro Standard), and the driver's adaptations cost of refraining to go by car to the inner city (observed when the congestion charging levels were increased) estimated by the case study on increases in congestion charge.

The social benefits are reduced health damaging emission (the effects on congestion levels are marginal, taking rebound effects into accounts). The social costs include adaptation cost for drivers and increased carbon emissions due to the fall in the sales of new diesel cars and the subsequent increase in the sales of new petrol cars. Since the energy efficiency of a diesel passenger, car diesel is typically higher than that of petrol cars (30%, as compared to 20%), the social cost per km that is not internalized by taxes is higher for petrol cars than for diesel cars. Moreover, the sales of diesel cars have a substantial effect on the carbon emissions in 2030 if the low diesel cars sales persist over time. The third cost is the cost of enforcement of the regulation.

Visits to the LEZ

Every year, Stockholm's inner-city cordon is passed approximately 148 million times by a motor vehicle, either entering or exiting the inner city. In the year 2022, 30.5 million (21 percent) of these passages would be non-compliant with the proposed light vehicle LEZ policy. Because of the natural renewal of the vehicle fleet, the number of non-compliant passages decreases quickly over time (see Figure 4). By year 2026 non-compliant passages already reduced by half. And by year 2030 only 7.3 million passages (5 percent of total traffic) would be non-compliant with the light vehicle LEZ policy.

Most of the non-compliant light visiting vehicles only visit the inner city infrequently, particularly privately-owned cars. For example, in year 2022, only around 90,000 out of the 385,000 unique light visiting non-compliant vehicles would have made more than three return-trips to the inner city per month. For this reason, the effect on congestion of the LEZ will be limited. However, this limited number of frequently visiting vehicles stands for the majority of non-compliant passages (see Figure 5).

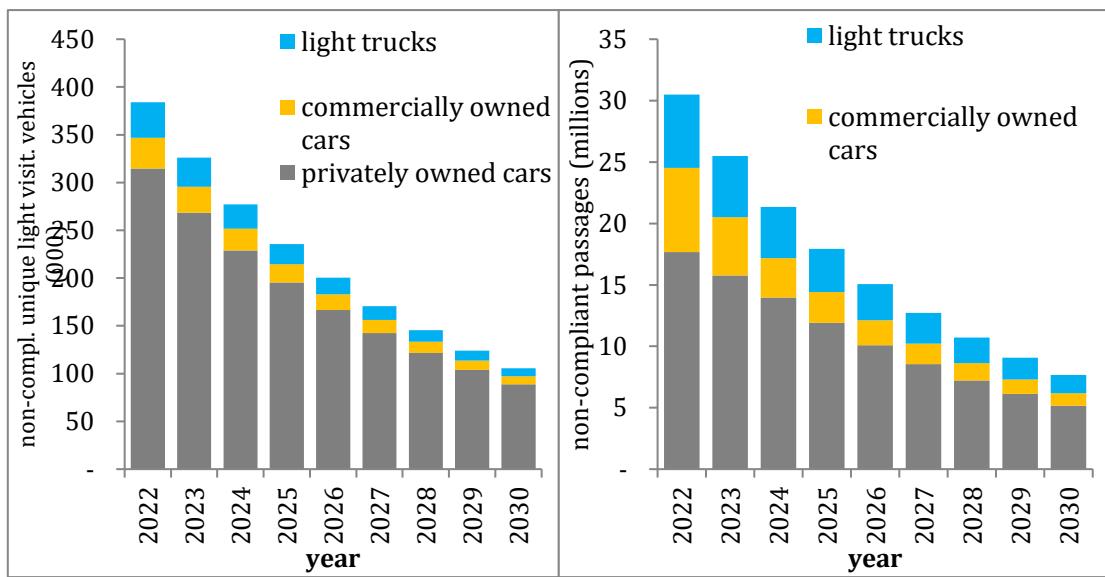


Figure 4. Base case forecast of the number of unique Swedish light vehicles that visit the inner city that would not comply with the LEZ policy; and base case forecast of the number of annual passages (entering or exiting the inner-city) that would be made by these non-compliant vehicles

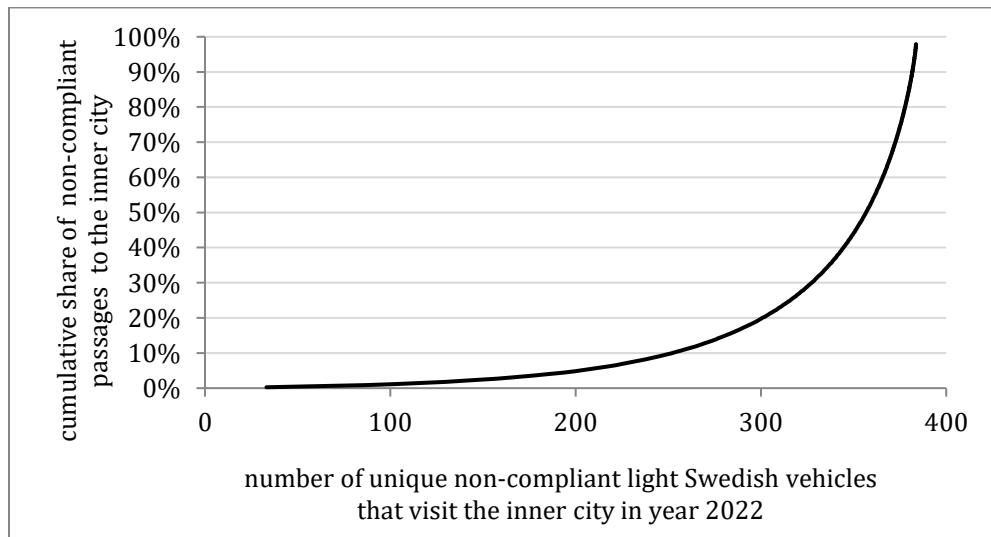


Figure 5. Cumulative distribution of the passages to the inner city among unique Swedish light non-compliant vehicles that visit the inner city in year 2022

Effects on air pollution

Figure 6 shows the baseline forecast for annual average NOx concentrations on Stockholm's most polluted inner-city street. Note the quickly decreasing NOx contribution from heavy traffic, due to a growing share of heavy goods vehicles having Euro VI emission standard, which is 11 times less polluting than Euro V standard. The shift to Euro VI is partly due to natural fleet renewal and partly because the heavy LEZ will require this standard from year 2021. Only around 18,000 unique Swedish heavy goods vehicles visit Stockholm's inner city per year. Compare this to the 1.3 million unique light Swedish vehicles visiting. Thus, heavy vehicles currently contribute a major part of NOx emissions from traffic, while comprising a small share of traffic and a small number of unique visiting vehicles.

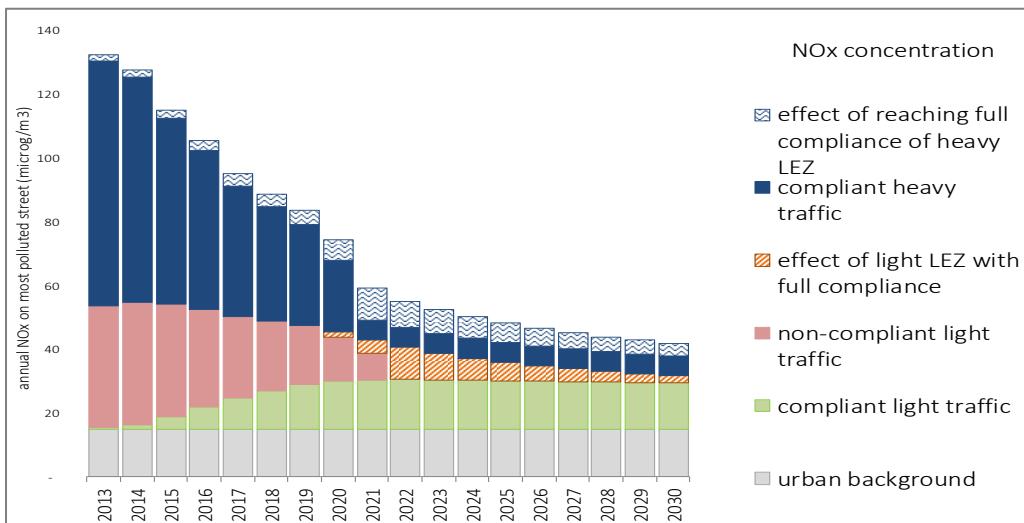


Figure 6. Forecast of NOx concentrations at Stockholm's most polluted inner-city street

Adaptation cost

In the study we outline and compare the results of two possible ways of assessing the adaptation costs to a LEZ zone: we call the first on “the road approach” and the second “the car market approach”. The on the road approach is based on the number of trips made with non-compliant vehicles to the LEZ area in the situation where the LEZ regulation does not apply, T and the average adaptation costs for these trips c . The total welfare loss of the adaptation to the LEZ is then Tc . Estimating c is difficult, but the advantage of Stockholm in this respect is that the monitoring of the effects of increases in the congestion charges allows an assessment of the adaptation cost. The congestion charging system is designed as a toll cordon, basically encompassing the same area as the base case LEZ zone. We assess the average adaptation cost c based on the observed the changes in the total traffic volume across the toll cordon in response to increases in the level of the congestion charge (assuming a linear demand function). An advantage of this approach is that the adaptation will be sensitive to the exact design of the zone, and so can be used to optimize the zone design.

The second approach, the car market approach, computes the adaptation cost from changes in prices on the second-hand car market (since the government's legislation on LEZ was introduced, the immediate effect was a price fall of second-hand diesel cars). We thus assume that the changes in the prices reflects the changes in the long-run service qualities of different cars due to the LEZ. (This approach is analogue to the rational market hypothesis in finance, where it is assumed that

share prices accurately reflect the long-run pay-off of shares.) We compute the adaptation costs in two steps: first a change in the demand for diesel cars (by model of the year), which induces a price change in diesel cars: and then second-order effects on gasoline and diesel cars by model of the year.

Results and policy advice

Preliminary results imply that adaptation costs are many times higher than the benefits for LEZ for light vehicles. This is mainly because many light vehicles visiting the city very rarely are banned on the LEZ. However, another large factor is that mainly heavy vehicles give rise to most health damaging emissions. Hence, imposing LEZ for heavy vehicles is a very good idea, which also is easier for the government to enforce.

Impacts of on-street parking fees in the suburbs of Stockholm

A new parking policy (Stockholm mobility strategy) was introduced to the area of Stockholm inner city in 2014, and the parking fee rate was increased. In the autumn of 2016, Stockholm extended parking fees geographically to include the southern inner suburbs, where street parking previously had been free. This study analyses an on-street parking count conducted before and after the introduction of parking fees in three inner suburbs of Stockholm, 07.00-19.00, during workdays. The data is conducted by floating car measurements. We control for seasonal effect (different months of the year), weekday and the temporal variation over a day. Specifically, we explore how the introduction of parking fees on curb parking affects the demand for parking. We also explore how it impacts on the demand for parking at different weekdays and time of day.

The data collection is based on video recording of the street-parking spaces on the selected road stretches, a floating car equipped with data logger and GPS system for automatic position determination. Video registration took place in the direction of the car, where the number of parked cars on both sides of the street was counted.

The pattern and variation in the number of parked cars for the three time periods is almost the identical with a clear shift in the level of the number of parked cars for the measurements from autumn 2017. The two time periods after the introduction of parking fees, spring 2017 and autumn 2017, indicate that the shift in total number of parked cars happened after the introduction of parking fees.

Comparing the mean number of parked cars for the road stretches shows a substantial decrease between spring 2016, without parking fees, and spring 2017, with parking fees (Figure 7). All comparisons are statistically significant at least at the 5%-significance level.

Policy advice

Introducing parking charges on curb parking in the residential area clearly has a large effect on the number of vehicles parked. However, it is less clear that it has affected car ownership. A possible risk is that parking charges has increased the propensity to driving to work, for those not having to pay the congestion charge and having free parking at work. However, since these are likely to be a limited number, the effect is likely to consist mostly on parking choice and car ownership.

Satisfaction with crowding and other attributes in public transport

Stated Choice (SC) and Revealed Preference (RP) studies find high valuations of crowding in public transport. Analysing Customer Satisfaction Survey (CSS) data collected in Stockholm 2008-2016, we find, however, that the explanatory power of the satisfaction with crowding on trip satisfaction is moderate, until crowding reaches very high levels. A relevant question is of course whether this

is consistent with the relatively high valuation of crowding in SP studies. In this study, we explore satisfaction with crowding among public transport passengers in Stockholm, and to what extent satisfaction with crowding can explain trip satisfaction. For comparison, we also explore the satisfaction with and explanatory power of other attributes. The explanatory power of different attributes on trip satisfaction is modelled by applying a discrete ordered choice modelling following the tradition of earlier literature. We follow and interpret the explanatory power of an attribute as importance. Since crowding levels has increased over time and differ across modes, we also explore how satisfaction with crowding and other quality attributes has evolved over time, and how it differs among modes.

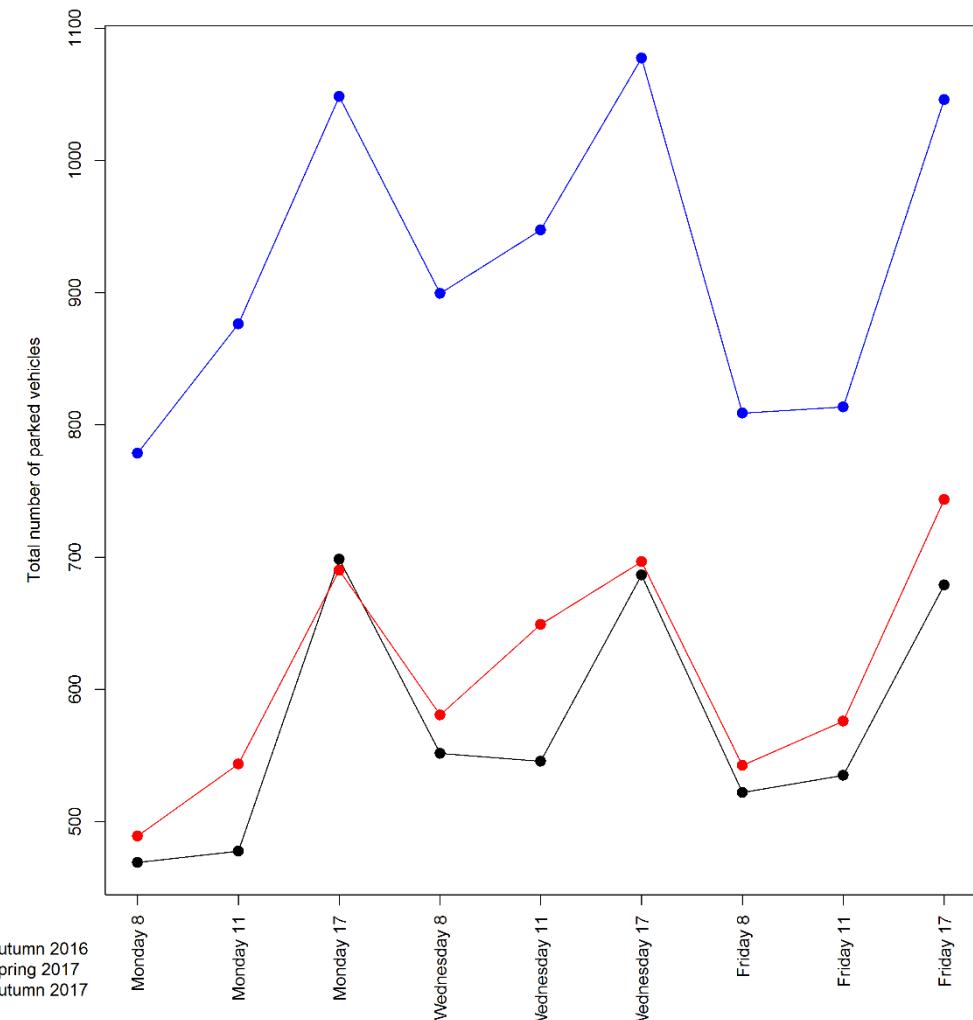


Figure 7. Total number of parked cars in all study areas in autumn 2016, spring 2017 and autumn 2017

We use the Stockholm Customer Satisfaction Survey 2008-2016 and automatic location and passenger counts from vehicles operating in Stockholm in 2014. To explore the relationship between the performance level, satisfaction and importance of the attribute, we also compare the satisfaction data from 2014 with the gathered vehicle location and passenger count data for the same year.

Figure 8 shows the share of satisfied respondents (giving the relevant attribute a grade above four) for crowding, reliability and trip satisfaction throughout the 16 years in which the CSS has been conducted. The trip satisfaction shows a steady trend increase. In fact, most of the quality attributes display a trend increase in satisfaction. The trend of satisfaction with reliability closely follows the trip satisfaction trend. The satisfaction with crowding, on the other hand, displays a trend decline until 2013, which is consistent with the increase in occupancy level.

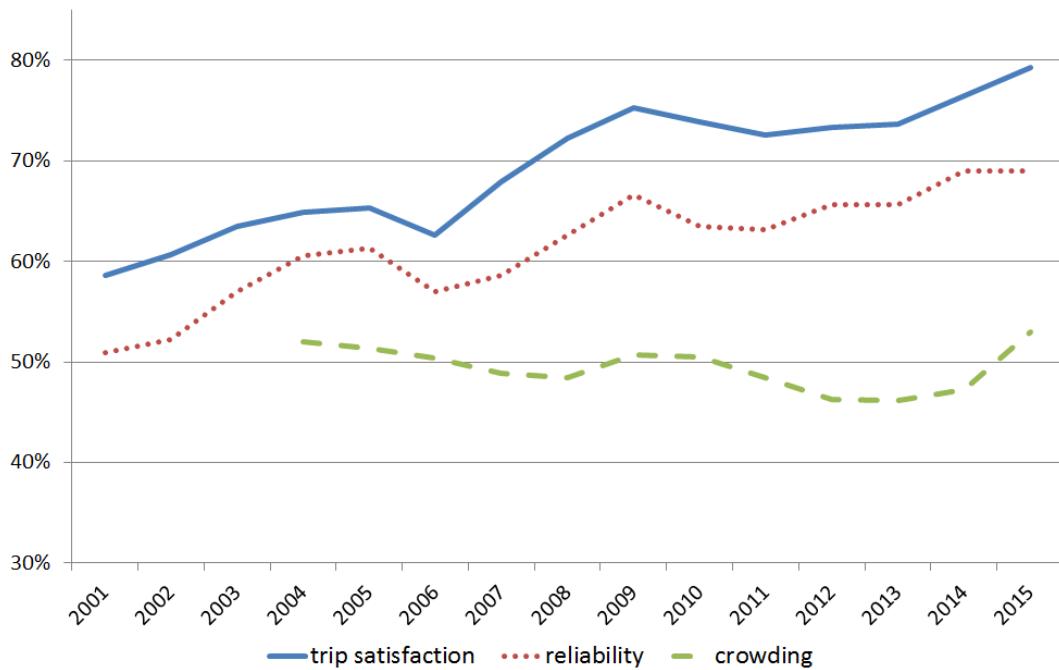


Figure 8. The share of respondents satisfied by crowding, reliability and giving their line a grade above four (trip satisfaction) over time in the survey conducted since 2001.

Findings

We find a strong relationship between performance level and satisfaction for crowding and reliability. Moreover, we find that the satisfaction with different attributes varies across modes in the way that is expected from the performance level and that satisfaction with all attributes except congestion has increased over time for all attributes. One puzzling result of this study is that, although the importance of crowding is low unless it reaches very high levels, crowding is still the attribute with the lowest satisfaction levels. The low importance attributed by most travellers is not consistent with the high valuation of crowding found in many valuation studies, or the public debate where crowding in the public transport system is seen as a major and increasing problem, justifying mega investments.

Policy implications

Crowding in public transport is increasing in many metropolitan areas, and capacity extensions addressing the increasing crowding often requires large costs (in particular in European built-up cities). Assessing the economic rationale for such extensions is key to an efficient use of public resources and an efficient design of the transport systems: an improved understanding of traveller's satisfaction and valuation of crowding are therefore highly policy relevant.

Cost-benefit exercises use valuations of crowding derived from stated choice and possibly (a small number of) revealed preference data. This practice relies on the assumption that the valuations of crowding reflect stable preferences based on the rationality that therefore impact the passengers' behaviour. The low importance of crowding that this study finds in combination with low satisfaction in large parts of the network suggests that SP studies might overestimate the valuation of crowding when crowding is below some threshold. This provides a warning to policy-makers to act on to high valuation of crowding when it is moderate.

In tandem with the increasing use of crowding in cost-benefit calculations, customer satisfaction studies are increasingly used in the planning and design process of the public transport system. Customer satisfaction studies are increasingly used to monitor and steer public transport production in Europe, whether they are studies constructed in a single public transport system (as the Stockholm CSS reported in this article) or nationwide (as the Transport focus studies from UK) or as a multilateral benchmarking project in the form of BEST (best2005.net) between Berlin, Copenhagen, Geneva, Helsinki, Oslo, Stockholm and Vienna. The objectives of these surveys include improving the understanding of consumers' perceptions and views of the public transport systems and to monitor the performance of the public transport system. They are also used to craft strategies to achieve political objectives for the public transport system (related to increased market share for public transport, revenues and customer satisfaction).

References

- ✓ Bastian, A., Börjesson, M., 2015. Peak car? Drivers of the recent decline in Swedish car use. *Transport Policy* 42, 94–102. <https://doi.org/10.1016/j.trapol.2015.05.005>
- ✓ Bastian, A., Börjesson, M., Eliasson, J., 2016. Explaining “peak car” with economic variables. *Transportation Research Part A: Policy and Practice* 88, 236–250. <https://doi.org/10.1016/j.tra.2016.04.005>
- ✓ Börjesson, M., Eliasson, J., Hugosson, M.B., Brundell-Freij, K., 2012. The Stockholm congestion charges—5 years on. Effects, acceptability and lessons learnt. *Transport Policy* 20, 1–12. <https://doi.org/10.1016/j.trapol.2011.11.001>
- ✓ City of Gothenburg, 2013. Förändrade resvanor: Trängselkattens effekter på resandet i Göteborg (Altered travel behaviour: The congestion charge and its effect on travel in Gothenburg).
- ✓ Evans, R., 2008. Demand elasticities for car trips to central London as revealed by the Central London Congestion Charge. *Transport For London Policy Analysis Division*.
- ✓ Jones, P., 2003. Acceptability of Road User Charging: Meeting the Challenge, in: Schade, J., Schlag, B. (Eds.), *Acceptability of Transport Pricing Strategies*. Elsevier, Oxford.
- ✓ Mellin, A., Nilsson, J.-E., Pyddoke, R., 2011. Underlagsrapport till RiR 2011:28: Medfinansiering av statlig infrastruktur.
- ✓ Schade, J., Schlag, B., 2003. Acceptability of urban transport pricing strategies. *Transportation Research Part F: Traffic Psychology and Behaviour* 6, 45–61. [https://doi.org/10.1016/S1369-8478\(02\)00046-3](https://doi.org/10.1016/S1369-8478(02)00046-3)
- ✓ The Stockholm Agreement, 2013. Utbyggd tunnelbana för fler bostäder (Extended metro for more housing).

Case study:

Vienna



Many cities, including Vienna, use parking policies to regulate traffic. By imposing prices for parking, drivers are incentivized to use alternative transport modes, leading to less traffic (also due to a lower extent of cruising for parking). In practice, parking policies often act as a substitute for road pricing, as parking policies tend to be more accepted by the public than road pricing. Our research adds light to the following questions:

- How do parking fees affect parking availability? (see section on “Parking price elasticities”)
- How can the effectiveness of parking policies be assessed? (see section on “Measurement of parking”)
- Do spatially differentiated and time-varying parking fees reduce congestion? (see section on “Innovative parking price policies”)

Objectives of parking policies

Parking policies typically have two objectives:

1. Parking regulations are designed such that **occupancy** of parking space
 - a. is kept at levels that are low enough to **ensure that drivers do not need lengthy cruises** to find a free parking lot
 - b. and the available parking space is “well” utilized.
2. Parking regulations also strive to **reduce traffic** in a city. Policy makers often see them as a substitute for more controversial policies, such as road tolls.

Parking price components

Drivers may pay parking fees per

- **Parking event**, i.e. a vehicle pulls-in/-out or enters/ exits a parking lot, facility or area.
- **Dwell time**, i.e. parking duration at a specific parking lot, facility or area.
- **Permit**, i.e. right to parking at a specific parking lot, facility or area.

Often there is price discrimination in parking pricing: long-term and regular parkers pay a flat rate for the permit to use a parking facility. Short-term and irregular parkers pay per event or dwell time.

Relationships in parking

- Parking **occupancy** is the ratio of utilized parking spots and the total parking supply. The lower the parking occupancy, the faster drivers find a free parking space. However, the relationship is not linear. Changes at higher levels of occupancy have a stronger effect on parking search time.
- Parking occupancy is affected by **parking volume** (the number of cars parking) and **parking dwell time** (how long each car parks).
- The **price elasticity of parking occupancy (EPO)** is defined as the percentage change in occupancy divided by the percentage change in parking fees.
- The **price elasticity of parking dwell-time (EPD)** measures the percentage change in dwell time divided by the percentage change in parking fees.
- The **price elasticity of parking volume (EPV)** measures the percentage change in volume divided by the percentage change in parking fees.
- EPO equals EPD plus EPV if the occupancy is per time unit, i.e. occupancy equals demanded parking hours divided by supplied hours. If the unit of occupancy is defined for a time instance, EPO approaches EPD plus EPV with a large and randomized sample.
- Drivers may react to increases in parking prices by changing **their activity or parking location**. The EPO increases in the availability of substitutes. These include alternative parking locations (changing parking garage), alternative modes, and by the driver's flexibility with respect to the underlying activity (e.g., by adjusting arrival and/or departure time, duration, location, or abandoning the activity altogether).

As an illustration, in Figure 1 we can see how 84 commuters who were interviewed before and after the introduction of a short-term-parking zone (SPZ) in Vienna's 18th district (Währing) reacted to the introduction of these zones. They allow residents to obtain permits for free parking, while non-residents are required to pay for parking and face maximum parking time restrictions. We found that the majority of commuters (i.e. non-residents) who parked in the 18th district on-street before the introduction of the SPZ, parked in off-street facilities or gave up driving completely after the new regulation. The example shows that commuters switch to a variety of alternatives if parking laws and prices change. These alternatives include options where commuters continue to drive by car and options where they switch to alternative modes.

- Higher parking fees may under certain conditions lead to more volume (i.e., more traffic), in particular when the EPD is high. In that case, a price increase leads to lower dwell times, which implies a lower occupancy. Given a low occupancy, parking is more attractive. The higher attractiveness of parking may lead to a higher volume. The newly attracted demand may lead to an increase in occupancy that outweighs the decrease in occupancy due to the lower price.

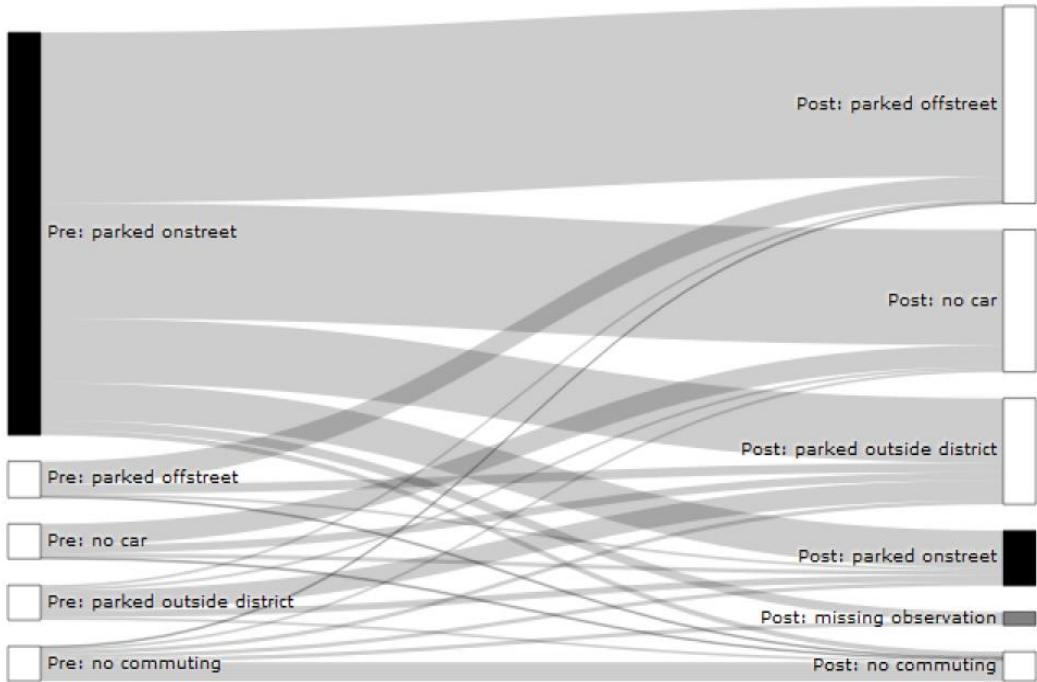


Figure 1. Parking Behaviour: Pre- and post SPZ

Parking price elasticities

By reviewing 50 studies and quantitatively summarizing them, we show that, as expected, changes in parking fees lead to changes in occupancy.

For the investigated studies, we find a baseline EPO of -1.18 for non-commuting parking events. A price increase of 10% at a non-commuting facility (i.e., no commuting garage) leads on average to 8.6% fewer vehicles parking. Additionally, drivers park on average 3.2% shorter, when (time-dependent) prices increase by 10%. The lower volume and dwell times lead to a decrease in occupancy by 11.8%.

For facilities offering parking to commuters, we find an EPO of -1.06. Commuters do not or only slightly adapt their dwell time as they tend to be fairly inflexible in the time they have to spend at work. Thus, a price increase of 10% does not only lead to 10.1% fewer parking events for commuters (as identified in the meta-analysis), but also to 10.1% fewer demanded parking hours.

Parking elasticities vary due to the following factors:

- On average the EPO is lower by 0.17 when drivers cannot switch to other modes.
- On average the EPO is lower by 0.33, when drivers cannot switch to other parking facilities.
- Price elasticities measured in real situations are considerably (by 0.55) lower than those measured in hypothetical situations. One plausible explanation may be supply restrictions. In real life, not all drivers can satisfy their parking preference due to supply restrictions (i.e., occupancy cannot be higher than 100%). Stated Preference (SP) studies, i.e. studies conducted in hypothetical settings, generally do not account for supply restrictions and latent demand. They typically assume that all drivers can satisfy their parking needs, and that supply is entirely elastic.

We can see in Figure 2 how the availability of substitutes moderates the effect of the EPO:

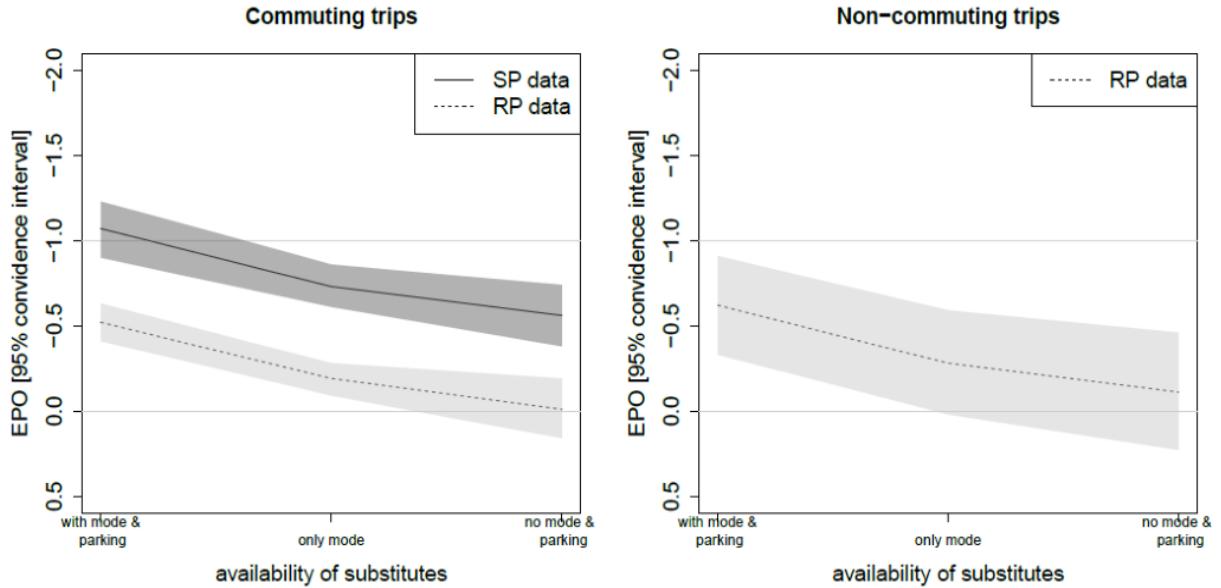


Figure 2. Elasticity predictions by the availability of substitution

Measurement of parking

How occupancy, volume, and dwell-time are measured is important for assessing parking policies. Parking occupancy, volume, and dwell-time can be measured by:

- **Parking infrastructure data** (e.g., parking meters, barriers) record current occupancy, volume or dwell-time. For collecting these data, often the same infrastructure is used as for the selling parking tickets.
- **Exterior-count data** (e.g., floating cars, satellites) record the current occupancy. The tools used to measure occupancy are not permanently installed. They are just used when needed.
- **Questionnaires** (e.g., surveys, personal interviews) record past parking events or parking intentions. With questionnaires also hypothetical scenarios can be tested.
- **Participatory sensing data** (e.g., apps, connected cars) record parking events of vehicles. Given a large enough sample and information about parking supply, the parking occupancy within a region can be calculated.

We co-developed an app generating **participatory sensing data** to measure parking events and commuting:

- Available for iOS and Android
- The software solution infers **whether, where and when** an app user parks (pulls-in) on a specific day. App transfers acceleration and location data from smartphone to a server. An algorithm based on machine learning automatically reconstructs and classifies trips. The solution can classify eight different modes (i.e., walking, biking, car, motorbike, bus, train, tram and subway).
- Algorithms infer whether the parking event was for commuting to work.
- In another application, we showed how **participatory sensing data** can be used to evaluate parking policies.
- We use data from the parking app Parkbob (www.parkbob.com).

- Parkbob developed an app that records when and where drivers pull-in or pull-out from a parking spot.
- Using these data we calculated (relative) occupancy, volume and dwell time for our sample.
- Additionally, we estimated the residency of our sample (using algorithms) and separated our sample into visitors and locals. Visitor parking includes all parking events conducted by person not living in the specific district. We define local parking as consisting of all parking events conducted by residents of the specific district within their district, excluding parking events at home.
- We predicted the effect of a newly introduced short-term parking zone (SPZ) for Vienna's 10th district (Favoriten), controlling for spatial (regional) dependencies, time effects and growth in app users.
- We can see the results in Figure 3. The dotted line shows the average occupancy, volume and dwell time for our sample before the introduction of the SPZ, while the line marked by squared shows the ex-post situation. The figures show how the indicators develop throughout an average working day. We can see that the occupancy level is lower after the SPZ than before for visitors and locals. The SPZ hence increased the parking availability within the district and reduced search times.
- Based on our sample, locals and visitors reacted differently to the SPZ introduction. Visitors park shorter under the SPZ, whereas locals park less within the district. In total the SPZ lead to lower occupancy.

Advantages and disadvantages of participatory sensing data based on the data from our use case:

Advantages	Disadvantages
<ul style="list-style-type: none"> ▪ Very detailed information about timing and location of parking events ▪ Low costs to collect the data ▪ Behavioral insights can be gained (persons can be tracked over time by their phone ID) ▪ Volume and dwell-time can be estimated ▪ Big sample size in terms of users 	<ul style="list-style-type: none"> ▪ No information about supply, hence occupancy can only be compared in relative terms, but the absolute level cannot be measured as only a minor share of car drivers has the app installed ▪ Parking events are not always detected (false positives and negatives), measurement error ▪ Small sample size in terms of parking events per user ▪ Sampling biases: the users of the app may not be representative

The quality of the data increases:

- as more people use the app;
- with a higher detection rate of parking events;
- with fewer false-positives (i.e., app records a parking event even if there was none);
- with a higher accuracy and precision of the GPS information.

Participatory sensing data seem to be very promising for the assessment of parking policies in the medium run. In the future, it is very likely, that connected cars will collect and share parking events, similar to what the Parkbob app does today. In addition, recent technological improvement (i.e., launch of third-generation GPS satellites, smartphones with dual-frequency GPS, software improvements on smartphones) point to an improvement in GPS accuracy in the near future. With more advanced data parking policies can be evaluated better and also spatially differentiated and time-varying can be implemented and enforced more efficiently. The concept of spatially differentiated and time-varying is explained in the following chapter.

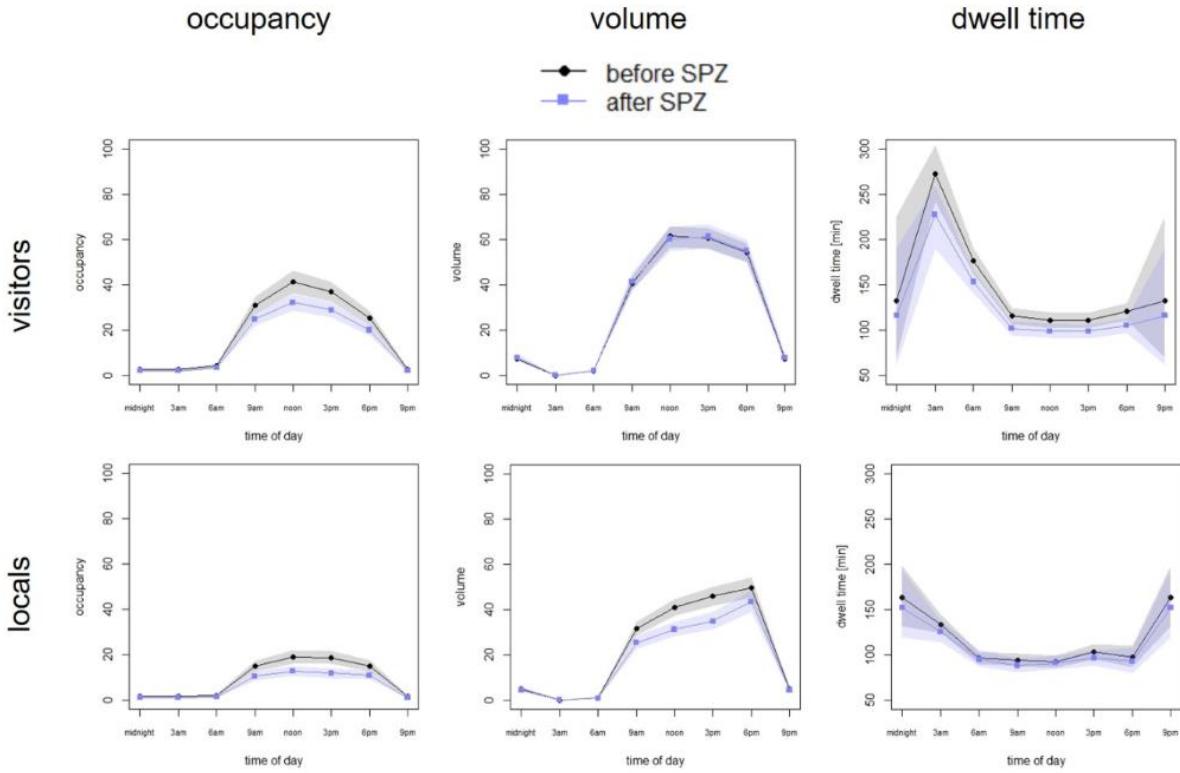


Figure 3. Occupancy, volume and dwell time before and after the SPZ

Innovative parking price policies

- Parking fees should in most cases be **spatially differentiated**. Some regions attract more cars than others. For instance, there is usually a higher demand for parking in the city center than in the suburbs. Parking fees should account for that.
- Parking fees should in most cases be **time-varying**. Parking demand tends to vary over time of the day. For instance, most commuters “prefer” to arrive at work in the morning, often due to own constraints or constraints imposed by the employers, leading to pronounced rush-hour effects on the road. Time-differentiated parking fees can incentivize drivers to shift their arrival times.
- Parking fees should be **dwell-time dependent** if occupancy is high and drivers are able to adjust their dwell time. The latter usually does not apply to parking in a commuting context.

In a field experiment using participatory sensing data, we tested spatially differentiated and time-varying parking fees for commuters in a real-life setting. In line with our recruitment criteria, all commuters in our sample usually drive by car to work on five days per week (according to their self-reported behavior before the start of the experiment). We recruited persons living outside of Vienna and commuting to Vienna. After one week of pre-measurement, participants faced virtual parking fees that were deducted from an initial budget. The remainder of the budget was paid out at the end of the experiment (i.e. after 1 week pre-measurement, 1 week treatment, 1 week post-measurement). The parking fees were structured as follows:

- Parking fees were charged depending on where and when the car was parked after finishing the morning commute. The fees were not dwell-time dependent.

- In Figure 4 we can see how the maximum parking fees that were charged on a specific day (varying between 5 and 25 Euros; see below) were discounted depending on parking timing and location according to the following formula:

$$\text{Parking fee} = \text{Maximum parking fee} \times (1 - \text{Location discount}) \\ \times (1 - \text{Time discount})$$

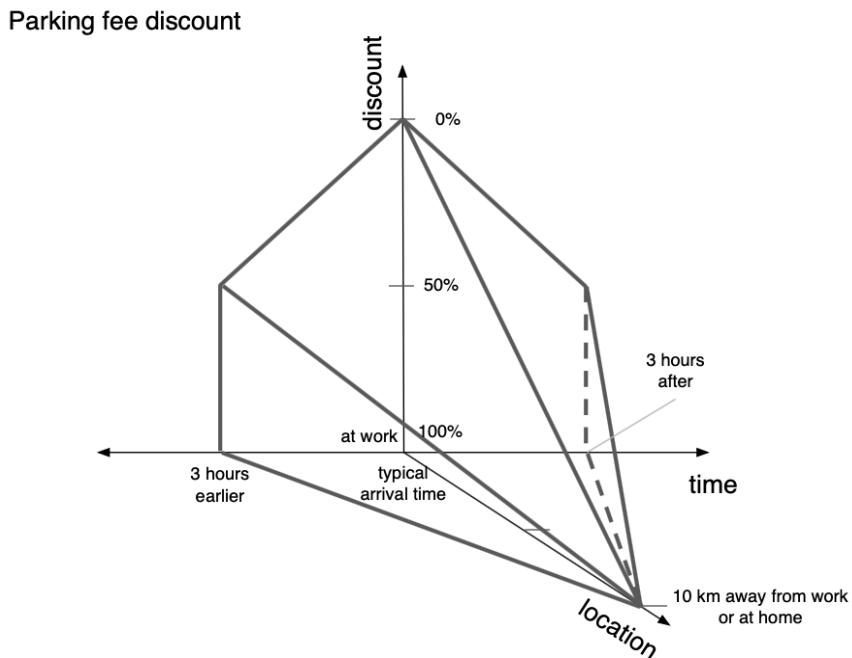


Figure 4. Structure of parking fees in experiment

- Parking fees were the highest at the commuters' workplace. They decreased linearly with distance from the workplace to 0 EUR 10km from work or at home (depending on which of the two location is closer to work).
- Parking fees were highest at the typical arrival time of the commuters (as reported in the questionnaire). They decreased linearly up to 50% 3 hours before and after the typical arrival time. Additionally, the fees were set to 0 EUR if the parking event took place 3 hours before or after the typical arrival time.
- Maximum parking fees were 0 EUR in the first and the fifth (last) week of the experiment. In week 2-4 they were 5 EUR, 10 EUR, 15 EUR or 25 EUR. They did not vary between the weekdays and were only charged from Monday to Friday. Parking fees were charged for all car trips, including car pooling and taxi.

In Figure 5 we can see the behaviour of 10 participants (out of overall 95 participants) who have been identified as having changed their behavior in the treatment phase. The majority of the participants did not exhibit any significant adaptations in their commuting behavior (regarding parking location and/or timing for their morning commute).

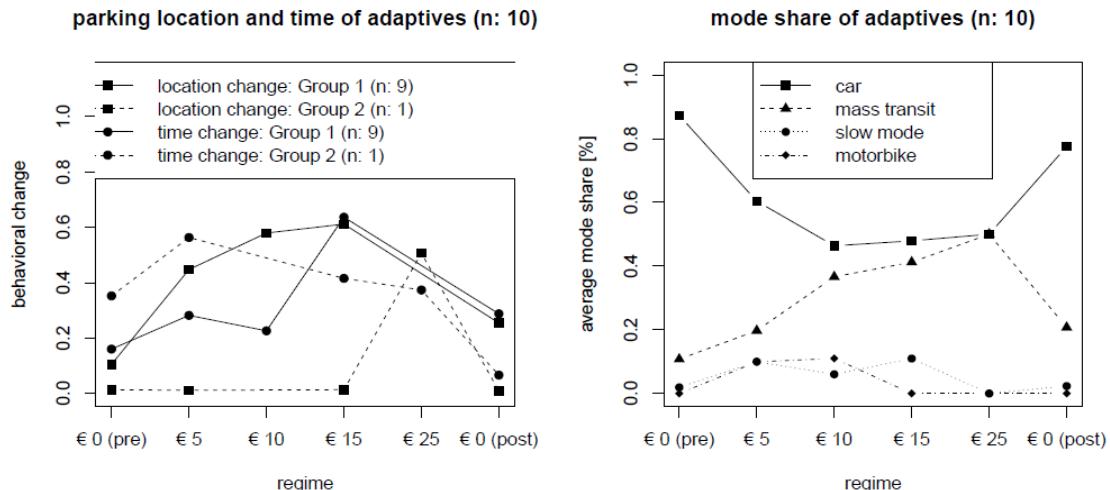


Figure 5. Parking location, time and mode share of adaptives during the experiment

- For the group of those who adapted we find that both changes in parking timing and in parking location have occurred.
- In the right picture in Figure 7 we see that commuters who changed mode mostly switched to mass transit. However, also the mode share of slow modes and motorbikes increases under higher parking fees.

Only 10 out of 95 commuters seem to have significantly changed their parking behavior during the experiment. We identified the following reasons:

- **Lack of flexibility in arrival time at work:** commuters who were more flexible in their arrival time at work are more likely to change their parking location and parking time.
- **Lack of understanding concerning the price regimes:** commuters who indicated that they understood the instructions of the experiment well are more likely to change their parking location. It might be an indication that time-varying parking fees are hard for commuters to understand.
- **Lack of good alternatives** most commuters said that using alternative transportation modes take too long and is too cumbersome. However, alternative transportation is not more attractive for commuters who have been identified as having changed their behavior than for those who did not.
- **Sample:** All participants indicated that they commute to work per car on five days per week (before even knowing about the experiment). If they had an attractive alternative to the car, they would likely have used that already before the experiment.

Policy implications

Elasticities

- The estimates for the EPO based on RP data indicate that generally there is a high potential to raise revenues of on-street parking and garages by increasing parking fees. The potential to raise revenues is also high for commuter parking. Predictions based on SP data yield a less optimistic picture for commuter parking, with the EPO not being significantly lower than 1 (in absolute terms).
- It is generally preferable to investigate the willingness to pay for parking rather than the elasticity associated with a single price change, as the former carries more generic information.

- In order to better understand the behavioral reactions to parking price changes, the available choice alternatives and their characteristics should be analyzed and reported in studies concerning parking price elasticities. Including quality features of parking and mode substitutes may lead to valuable insights on how substitutes and price policies should be coordinated to manage traffic effectively.

Policy design

- Drivers react to spatially differentiated, timely-varying and dwell-time dependent fees. An effective policy hence considers all three parking price components. How parking is priced determines how the driver can avoid or reduce parking cost. It affects her number of alternatives, and hence her elasticity.
- Pricing instruments without mode alternatives seem to be insufficient to steer commuters from suburban areas towards sustainable means of transportation. Based on the findings of our experiment with spatially and temporally differentiated parking prices, we can conclude that very high monetary incentives (in the range of 25 EUR per workday) might not be sufficient to change commuters' behavior, at least in the short run and if alternatives tend to be widely inferior. Similarly, our literature review shows that pricing instruments are more effective if parking and mode alternatives are available.
- Policies aiming to reduce cruising for parking should use dwell-time dependent parking fees for non-commuting parking facilities. In our case study in Währing (introduction of short-term parking zone (SPZ)) we can see, that drivers shorten their dwell time and give up parking within the priced area to avoid parking fees. Similarly, our meta-analysis shows that parking fees per hour lead to short dwell-times.
- Parking policies may affect residents differently than visitors. Residents of the Favoriten district react differently to parking fees than drivers who visit the neighborhood. Visitors did not park less often after introduction of the SPZ, but on average shorter. Locals parked less frequently, in spite of being able to obtain a parking permit. The parking permit authorizes residents to park free of charge within their district for a symbolic price of EUR 7.5 per month. The price amounts to less than 4 hours parking per month.

Data

- Participatory sensing data are promising data source for measuring and steering parking behavior. The technology is developing at a fast pace. With the upcoming of connected cars and better GPS accuracy, parking events can be tracked even more easily and efficiently in the future. Already now, participatory sensing data give valuable insights into how parking policies affect the parking behavior of different groups. Parking policies may affect residents differently than visitors. Residents of the Favoriten district react differently to parking fees than drivers who visit the neighborhood. Visitors did not park less often after introduction of the SPZ, but on average shorter. Locals parked less frequently, in spite of being able to obtain a parking permit. The parking permit authorizes residents to park free of charge within their district for a symbolic price of EUR 7.5 per month. The price amounts to less than 4 hours parking per month.

The IP-SUNTAN research team



Erik T. Verhoef, project leader, is full professor of and head of the department of Spatial Economics at **Vrije Universiteit Amsterdam**. In addition, he is fellow at the Tinbergen Institute. His research focuses on efficiency and equity aspects of spatial externalities and their economic regulation, in particular in transport, urban and spatial systems. Important research themes include second-best regulation, network- and spatial analysis and methodological development, efficiency aspects versus equity and social acceptability, industrial organization in network markets, valuation and behavioural modelling, and policy evaluation.



Devi Brands is PhD candidate at the department of Spatial Economics, **Vrije Universiteit Amsterdam**. His research topic is behavioural modelling of peak-hour commuting behaviour: stated and revealed preference approaches. His research interests cover applied econometrics, behavioural economics, environmental economics, inequality, transport economics.



Paul Koster is assistant professor at the department of Spatial Economics, **Vrije Universiteit Amsterdam**. He is also research fellow at the Tinbergen Institute. His research focuses on the valuation of non-market goods such as travel time and travel time variability and the regulation of externalities resulting from transportation. He works on explaining and understanding individual choice behavior using advanced discrete choice econometrics and connects behavioural models to economic evaluation of transport policies.



Jasper Knockaert is researcher at the department of Spatial Economics at **Vrije Universiteit Amsterdam**. His research focuses on travel behaviour which he analyzes using econometric models. Part of his research covers the design of large-scale real world experiments that deliver extended behavioural datasets. Previously, he worked at the Traffic Research Group and the Energy, Transport and Environment research group at the KU Leuven. He obtained an PhD at this same university.



Maria Börjesson is professor of economics at the **Swedish National Road and Transport Research Institute** in Stockholm. Her research interests include transport cost-benefit analysis, appraisal and sustainability, transport policy and pricing for all modes, public opinions, transport modelling, travel behaviour, gender differences, active mobility and cycling, the impact of the transport system on employment and productivity, railway economics, survey design, choice experiments, and econometrics for valuation of non-market goods such as travel time, reliability and security. She is also affiliated to the Choice modelling Centre, ITS Leeds.



Stefanie Peer works as an assistant professor (tenure track) at the Institute for Multilevel Governance and Development (**Vienna University of Economics and Business**). Her research focuses mostly on topics related to transport economics. She conducted her PhD research at the Department of Spatial Economics at the VU University Amsterdam, and defended her dissertation entitled “The economics of trip scheduling, travel time variability and traffic information” in 2013. She has published in various high-ranked journals, and is active in multiple scientific associations (NECTAR, ITEA, GfR).



Stephan Lehner is research assistant and PhD candidate of Transportation Economics at the Institute for Multi-Level Governance and Development (**Vienna University of Economics and Business**). Prior to his employment at WU, Stephan Lehner gained valuable professional experience in various positions in the field of corporate strategy and management consulting at – among others – OMV, AVNET, Contrast Ernst & Young and Fontin & Company Management Consulting. He finished both his bachelor's degree in Business Administration as well as his master's degree in Strategy, Innovation and Management Control at WU.

Experimental design

IP-SUNTAN has designed, followed, and analysed real-world implementations of a range of innovative tools, policy measures and strategies that aim at achieving a sustainable, yet efficient urban transport system. The project has focused on both “technology” in the sense that innovative ICT-based policies are central; and on “behaviour” as we have studied how these policies affect travellers’ choices in their daily mobility behaviour. Hence, the key policy to enhance accessibility that we focus on is not more infrastructure, but on how to use the existing infrastructure more efficiently.



This work package has planned the experimental design and data collection for several various policy implementations keeping a keen eye on the best practice and needs to the behavioural modelling. The experimental designs and data collections were developed for the case studies in such a way that the policy implementations are best served. Since the research questions at hand are different, and since the experimental design had to be adapted to the possibilities offered,

considering restrictions of legal, technological, administrative, integrity and financial nature, they differ between the case studies: from individual level data, to aggregate level and meta level data (see chapter 6 for an overview of data types). Some of the data are collected in controlled experiments, and other are collected from real-world implementations. Aggregate level data provides less opportunities to understand underlying mechanism but are on the other had often more representative and complete. We have in some case also developed the experimental design in collaborations with public agencies which also has meant restrictions in terms of data collections but opportunism in terms of implementations.

Still, in all case studies the data constitute the realistically best quality possible, allowing a robust assessment of the effects of the concepts and instruments tested in each if the difference case studies. In all cases we have paid special attention to self-selection of participants into experiments, and heterogeneity of participants. All cases have also involved careful considerations on how to control for observed and unobserved heterogeneity; the integration and joint optimization of stated and revealed preference data collection for behavioural modelling; and the design of experiments such that effects from incentives (policy instruments) can be properly identified. Central issues, besides cost-effectiveness in data collection, have been:

The Randstad Case Study

Tradable mobility permits: theoretical ingenuity or promising rush hour policy?

The aim of the lab-in-the-field experiment was to investigate how trade in mobility permits works in practice. A virtual experiment was conducted in which there are no effects on actual mobility behaviour, aiming at exploring the subjects understanding of and response to the experimental set up. The experiment was also designed in such a way that the supply and demand for mobility permits, and the price dynamics in the market for permits, could be explored. The experiment took place in December 2017 and consisted of two weeks. In the experiment, participants had to make a virtual parking choice on the mobile website every working day via their smartphone or computer. See for further info on the experimental design in Chapter 2.

The Swedish Case Studies

Stockholm and Gothenburg congestion charges (with Transport adm Head Office)

The increase in congestion and air quality problems in the metropolitan areas, calls for a range of policy instruments. Although congestion charging has been considered to be an efficient remedy to congestion problems for decades, implementation has been held back by lack of public and political support. Now, in two Swedish cities, Stockholm and Gothenburg, congestion charges have been implemented in full scale, providing us with a unique data sources regarding the behavioural response.

To be able to analyze the behavioural effect of the increased congestion charges, and the system extensions, we gained access to the traffic volume data collected by the changing system, by time of day and for different types of traffic (trucks, company cars and private passenger cars). This is novel data, because in previous analyses of the original systems, researchers have not gained access to data segmented on different types due to legal and integrity issued. The more detailed

data allows a more thorough analysis of the effect so the welfare effect and the distribution of the effects (equity). We also collected data on travel time changes in response to the increased charges by floating car measurements on the arterials of Stockholm. Still, micro-level data is not available due to legal and privacy issues.

Now, traffic volumes are subject to substantial seasonal variation. Traffic volumes are also influenced by many external factors: such as GDP, population growth and fuel prices. In the analysis of the effects of the charges, we have therefore controlled for seasonal variation by comparing the traffic volumes of different years for the same season. Because we explore changes in yearly data, we also need to control for the impact on traffic volumes of external factors. This will give an estimate of what the traffic reduction would have been if these external factors had remained constant. To do this, we use a time series model estimated specifically from data on traffic flow across the cordon 1973-2005 (before charges were implemented). Its explanatory variables are employment in the county, fuel price and relative car ownership (several other variables were also tested but added no explanatory power). The largest effect comes from changes in total employment, as expected, which increases car traffic nearly proportionally. The fuel price elasticity was estimated to -0.3, which corresponds well with what is usually found in the literature.

Moreover, since the public opinion is a key reason why not more cities have introduced congestion charges, we also analyse the long-term effect on the public opinion of congestion charges. In particular, we explore the impact on the public opinion of the changes of the systems. To explore the public opinion, we have set up the design of collection of attitudinal surveys in Stockholm and Gothenburg, in collaboration with the public agencies. These have been repeated over many years, such as changes over time in the public opinion can be analysed. We find that the public support increased in the two cities after their introduction until the systems were revised; since then, the public support has declined in both cities.

The importance of reducing crowding (with Public Transport Stockholm)

We use the Stockholm Customer satisfaction Survey 2008-2016 and automatic location and passenger counts for 2014 from vehicles operating in Stockholm. The Stockholm Customer Satisfaction Survey has been conducted since 2001, with ten survey waves per year.⁸ Before 2014, each survey wave included 9 000 interviews, but since 2014 each wave includes 10000 interviews. Paper questionnaires are distributed and collected on board to reduce self-selection bias and low response rates. They include statements concerning the satisfaction with nine quality attributes. The responses are given on a seven-point Likert scale, ranging from '7- agree completely' to '1-disagree completely'. The respondents are instructed to have in mind the usual conditions of the line they are using when stating their satisfaction. Hence, the respondents are tacitly asked to recall the travel conditions from previous trips on the line and state their satisfaction.

To explore the correlation between the actual performance level and the satisfaction with the attributes reliability and crowding, we also use data on travel time reliability of the buses, as well as passenger counts and load factors. Moreover, we use observations for buses where both automatic passenger count (APC) data and automatic vehicle location (AVL) data has been collected. All vehicles in the Stockholm Public Transport system are equipped with Automatic Vehicle Location (AVL). It measures the travel time and reliability for all services on all lines and modes. Approximately 10 percent of all buses and trains are also equipped with Automatic

⁸ Each wave is conducted for two weeks. One wave per month is conducted January-May and August-December.

Passenger Counts (APC), measuring number of boarding and alighting passengers and load factors between stops (APC is not used on the Metro).

Cost-benefit evaluation of environmental zones

(With City Stockholm)

When assessing costs and benefits of Low Emission Zone (LEZ) and developed a framework for that. We apply the framework to Stockholm, providing a unique opportunity of assessing these costs due to the micro data available from the congestion charging system, in terms of visiting frequencies to the inner city by vehicles type and age, and the driver's adaptations cost of refraining to go by car to the inner city (observed when the congestion charging levels were increased). We also use many other input sources vehicle registers 2013-2017, price drops of second-hand data, changes in the fuel types in the stakes of new vehicles compared to forecast issued in 2017 before the debate on LEZ zone started.

Impact of on-street parking fees South inner suburbs of Stockholm

(With City Stockholm)

The data collection is based on video recording of the street-parking spaces on the selected road stretches, a floating car equipped with data logger and GPS system for automatic position determination. Video registration took place in the direction of the car, where number of parked cars on both sides of the street was counted.

The on-street parking fee was introduced in January 2017. Our data were collected in three waves, the first in the autumn 2016, before the introduction of on-street parking fee, the second in spring of 2017 and the third in the autumn of 2017. The third wave took place exactly one year after the first wave such that we can control for seasonal effects. Each data collection wave took place for two weeks, including three-week days each: Monday, Wednesday and Friday. The total number of observations obtained in autumn 2016, in the spring 2017, and in the autumn 2017, respectively, is shown in Figure 7 (p. 23).

Every measurement day included three measure time-of-day periods; 8-10, 11-13 and 17-19. During each period the floating car made around 100 observation on 14 streets within the study area. When occupancy fluctuates strongly by time of day, as in our case, it is essential do the same routes at the same time all days. To control for this by making the same routs at the same time of day for all routes during all measurement days.

The Viennese Case Studies

Measuring behavioural changes after the extension of a parking management zone using survey data

Vienna uses parking management, mostly short-term parking zones (SPZ), as central policy instrument for steering mode choice and lower parking search times and traffic. Vienna's SPZs regulate curb parking within districts. The districts' residents can apply for a permit to park for an unlimited time within their district. Such a permit costs EUR 90 per year for the outer and EUR 120 per year for the central districts. For drivers without permit, parking dwell time is limited (2-3

hours) and subject to a charge (EUR 1.05 per 30 minutes). In the outer districts, visitors can park for a maximum of three hours, in the central districts, it is two. The implementation of SPZ is decided at the district level, often following referenda.

This study investigates commuters' reaction to the implementation of an SPZ in Vienna's 18th district (Währing) based on survey data. For the survey, we recruited commuters who are affected by this policy change, i.e. those who regularly parked in the 18th before the introduction of parking management, either because their workplace is located in the 18th or they parked in the 18th district but then switched to other modes of transport (walking, public transport, cycling) to access their final location outside of the 18th district. A before and after survey among commuters affected by the change in regulations has been conducted in summer and autumn 2016. For the first survey commuters were approached at street crossings by several surveyors. The second survey was then sent to those who filled in the first survey via e-mail and were members of our target group.



Measuring behavioural changes after the extension of a parking management zone using smartphone-based data

This study focuses on the effects of a short-term parking zone (SPZ: see description in the above-mentioned study) in major parts of Vienna's 10th district, which is the largest district in Vienna in terms of population (200.000) and one among the largest in terms of size (32m²). For the analysis we use innovative smartphone-based data on parking events.

The start-up Parkbob provides the data that we use in our analysis. The company developed an app that warns its users automatically when they park in areas with parking management. Furthermore, the app provides information on available on-street parking nearby. The app routinely collects parking events, which the app records automatically, not requiring any user interaction. A machine learning algorithm automatically recognizes parking events. A parking event is a car parking or pulling out of a parking space. In case a parking event is detected, the app sends the geo-coordinates, a timestamp and some meta information, including the unique phone id, to the servers of Parkbob. The server filters false positives. With the data, we can track phones and hence drivers over time.

The data allow us to infer information relevant to parking policy making. We can extract dwell times as well as utilization rates. Parking activities close to parking garages are excluded, as

different pricing schemes apply there. Most importantly, we can classify users based on the observed parking behaviour. In this study, we focus primarily on the differentiation between residents and visitors of the 10th district, as the former have access to buy a parking permit for the district, whereas the latter are not eligible for buying such permits. The residential address can be deducted from the information on where a specific user parks his/her car regularly during night hours. Visitors in contrast travel to the 10th district, however, not parking there overnight.

SPZs are expected to particularly affect the behaviour of visitors. They can react to the introduction of SPZs by 1. changing parking location, 2. switching mode, 3. shifting the start time of the underlying activity or activities, 4. abandoning the activity, and/or 5. shortening the duration of the underlying activity or activities. Residents who buy a permit in contrast may have more (curb) parking events within the district due to better availability of parking (if the number of visitors declines). Those who do not buy the permit may reduce their parking events within the district and/or shift their parking away from curb parking. We are only able to elicit the average effect for residents, as we do not have individual-level information on permit ownership.

Parking charges: a field experiment

To test how commuters react to spatially-differentiated and time-varying price policies we run a field experiment. Participants are full-time workers living outside Vienna and commuting to Vienna by car each workday. They participate in the experiment voluntarily. The design of the experiment incentivizes the participants to change their mode choice (away from car use) and scheduling behaviour (away from their usual arrival time) by offering them corresponding monetary incentives concerning their morning commute trip.

The experiment lasts 5 weeks: in the first and last week of the experiment (which we refer to as pre- and post-measurement, respectively), we only monitor the behaviour of the participants, but do not provide any monetary (or other) incentives to participants. During week 2 to 4, we expose the participants to a virtual, personalized parking price scheme. Individuals receive a virtual start budget before the experiment, from which daily parking charges (5, 10, 15 or 25 Euro) are deducted. If they do not change their behaviour during these three weeks (no switch in mode choice and no adaptations in arrival times), the maximum charge will be applicable for each day, and the remaining budget will be 0 at the end of the experiment (hence, no negative balance can occur). In the case of behavioural adaptations towards alternative modes and off-peak travel, the remaining budget (start budget minus parking fees) is transferred to the participants' bank account at the end of the experiment. Participants received no pay-out if the app measured less than three trips per week.

Participants could earn additional monetary rewards by filling in up to 20 stated preference questions throughout the experiment (EUR 1/question). The additional earnings were then added to the pay-out at the end of the experiment.

Participants had to install a dedicated smartphone app that allows for tracking their travel and parking behaviour, and capable of identifying the chosen transport mode. The smartphone app is also used to provide information to the participants, related to the level of parking fees and road tolls.

In addition to the data collected by the smartphone app, the participants also had to fill in an initial survey, which contained questions concerning their usual travel behaviour (e.g., the usual arrival time at work), socio-economic characteristics, as well as attitudinal questions. Moreover, at the end of the experiment, participants had to fill in a questionnaire concerning the evaluation of the

experiment and their own travel behaviour during the experiment. Finally, we used "Google Routes" to infer their door-to-door travel time by train and car from home to the city centre. These travel times are used in the analysis of the mode and departure time choices.

The target group for participants was quite narrowly defined: we recruited participants who commute from outside Vienna to Vienna. All invited participants drive at least five times per week to work by car and park their car close to their workplace. All participants work full time.

The recruitment process included two main steps. First, we invited commuters to participate in a survey, announcing that some of them will be invited to participate in an experiment with monetary payments, however, not mentioning what behaviours will lead to these payments. This was done in order to reduce potential selection biases. At the end of the survey, individuals who met the requirements for participating in the experiment (based on the self-reported information provided in the questionnaire), received an invitation to participate in the experiment. We employed multiple recruitment channels including (i) direct mailing via postal letters and e-mails, (ii) employers of potential participants, (iii) recruitment partners (a.o. Austrian chamber of labour, automobile association) and (iv) other strategies including Facebook ads and articles in local news.

Behavioural modelling

A main goal of IP-SUNTAN was to gain insights in the behaviour and preferences of travellers, in order to be able to better predict their reaction to changes in policies, in particular pricing policies. A specific focus was on models that are able to explain the travel behaviour of individuals that has been observed before and after the implementation of specific (pricing) policies and incentive schemes (which range from small-scale experimental interventions to district-wide policy changes). Most of our data sources thus have a panel structure, where the same individual (or location) is observed at multiple time instances. The initial specifications of the employed models build on existing theoretical as well as empirical models. However, the innovative character of the cases and data studied in this project renders enhancements of the existing models necessary.



Data types

Various estimation methods have been employed in IP-SUNTAN. The model selection depends, among others on the disaggregation level of the available data sources. In IP-SUNTAN, the following data sources have been used, which differ in terms of aggregation level:

- 1) **Individual level data** (data from individual travelers)
 - Remaining budget at the end of a lab experiment on parking permits (Case Study Amsterdam; Brands et al., 2019)
 - Travel behavior during a real-life experiment on temporally and spatially differentiated parking charges (Case Study Vienna; Lehner et al., 2018)
 - Stated preference data for participants of the above mentioned real-life experiment (Case Study Vienna)
 - Stated preference experiment long-run vs. short-run scheduling preferences (joint effort; Peer & Börjesson, 2018)
 - 2-wave questionnaire data on parking behavior before and after the implementation of parking management (Case Study Vienna)
 - Questionnaire data on the level of satisfaction with public transport (Case Study Stockholm)
 - App-based measurements of parking behavior where phone-IDs are followed over time (Case Study Vienna; Lehner et al, 2019)

- 2) **Aggregate level data** (aggregated over a group of individuals)
 - Traffic volume data (Case Study Stockholm)
 - Location and passenger count data from public transport vehicles (Case Study Stockholm)
 - On-street parking count data (Case Study Stockholm)
 - Prices on the second-hand car market (Case Study Stockholm)

- 3) **Meta level** (available studies on a specific subject)
 - Parking price elasticities (Case Study Vienna)

Note that in some cases individual level data are aggregated before model estimation (e.g. Lehner et al., 2019). The data type does hence not always correspond to the disaggregation level of the collected data. Moreover, often it is not feasible or desirable to track individuals in their behaviour, not at least because of privacy concerns. Traffic flow or passenger count data are one example in which often anonymized data are collected, although it might be technically possible to follow vehicles (via number plate recognition) and public transport users (e.g. via Chip cards).

Model types

We can generally differentiate between:

- (1) *Structural models*
- (2) *Reduced form models*

Structural models are derived from theory and aim at eliciting underlying preference structures, while reduced-form models typically establish relationships between an endogenous and a set of exogenous variables. Both model types have been employed in IP-SUNTAN.

Structural models are often estimated using discrete choice models, in which the full choice set of alternatives (regarding modes, departure/arrival time, etc.) and their attribute values (regarding travel time, costs, comfort, reliability, etc.) is specified. Reduced-form models are typically estimated using regression models, in which only the chosen alternative is considered. Both model types can adopt advanced econometric specifications that are for instance able to deal with self-selection, or observed and unobserved heterogeneity across individuals.

Discrete choice models are widely used in transport studies, as many choices faced by travellers are discrete in nature such as the choice between routes and transport modes, the purchase decision of vehicle and public transport passes, and even the decision between collecting different

types of information regarding travel-related decisions. We have used discrete choice models to estimate preference structures in multiple parts of the project.

Discrete choice models can generally only be estimated if the entire choice set can be defined in terms of alternatives and their attribute values. This is almost always the case in laboratory studies and stated preference experiments (e.g. Peer & Börjesson, 2018), where the researcher has full control over the design of the experiment. But it is much less the case in real-life settings, where often only attributes of chosen alternatives are observed. For instance, with GPS measurements of individual travel behavior (Lehner et al., 2018), observe only the chosen alternative is observed, but no information on how long the trip would have taken using alternative transport modes. Similarly, with app-based data on parking behavior (Lehner et al., 2019), only observe the actual parking event in terms of time and space is observed, but only limited information on where else the person could have parked is available. The same is true for questionnaire-based data on parking behavior before and after the introduction of parking management in the Viennese district "Währing". In such cases the estimation of choice models typically requires the collection of additional data, e.g. from online tools that allow for the computation of travel times for different modes of transport, or GIS-information on the location of parking garages.

Structural models are generally preferable over reduced form models as they yield more generic information on underlying preference structures. The estimates obtained from structural models can be used to obtain information on counterfactual policies, i.e. to forecast the effect of alternative policy designs (e.g. concerning the specification of a pricing scheme, or the geographical and/or temporal scope of a given policy) on aggregate measures such as the modal split or emissions. However, the estimation of structural models is often not feasible due to data requirements, in particular because such models require the attributes of the unchosen alternatives to be known.

Modelling reactions to changes in parking prices

Multiple case studies within IP-SUNTAN have investigated parking behaviour, mostly in the context of a (pricing) policy change. These studies use a wide array of different methods, depending on the available data source(s):

- Brands et al. (2019) conduct a lab experiment in which participants trade parking-permits. They run a standard OLS regression with the final budget that the participants have earned at the end of the lab experiment being the dependent variable. If the participant acts rational, the expected final budget is €10. Lower amounts indicate that not all choices were made rationally. The explanatory variables include for instance activity level during the experiment as well as various socio-economic variables.
- Data of the real-life experiment conducted among commuters living outside Vienna and working in Vienna are also analyzed by means of regression analysis (Lehner et al., 2018). For all 95 participants who have completed the experiment, two separate regressions are run which accounts for all trips taken by that person over the course of the 5-week experiment. The first regression tests whether the specific person changes her behavior significantly during the treatment period in terms of parking distance to work; the second regression tests whether she adjusts her parking time away from the usual parking time. The independent variables used in the two tests are the maximum applicable parking fees for a given trip and a dummy for the post-measurement.
- In Vienna, a survey has been conducted in 2 waves among persons parking (but not living) in a specific district ("Währing") for commuting purposes, in which a short-term parking zone is implemented (with paid parking for non-residents). They have been asked about their parking (and travel) behavior for a representative workweek before the introduction of the parking zone and after the introduction. Hence, overall, 10 observations per participant are available.

As data limitations do not allow for the estimation of a full-fledged choice model, various models for different behavioral alternatives (parking in the district where the parking zone is implemented, parking in another district, not traveling by car etc.) are run. The models explain whether a specific subject makes use of a specific alternative more or less often relative to the pre-measurement. Explanatory variables are, among others whether the person lives in Vienna, has a public transport pass, and has access to employer-provided parking.

- In the 10th district of Vienna (“Favoriten”) the introduction of a short-term parking zone (with paid parking for non-residents) has been evaluated (Lehner et al., 2019). Here, app-based measurements of parking events were used. A panel structure was provided because phone-IDs were followed over time. Based on the parking activities the phone owners were classified as residents or non-residents of the Favoriten district and analyze the impact of the short-term parking zone separately for these two groups. Lehner et al. (2019) use a Spatial Multilevel Bayesian model to estimate how the introduction of the SPZ affected occupancy, volume and dwell time of persons belonging to one of the two groups. They aggregate the number of parking events over 3-hour time slots and districts, and hence do not perform the analysis at the level of the individual driver. In a robustness check they further test for spatial autocorrelation in a separate estimation.
- Another study analyses the introduction of parking fees in three inner suburbs of Stockholm. The data collection was conducted by floating car measurements, which counted the number of parked vehicles on both sides of the road. The econometric model controls for seasonal effect (different months of the year), weekday and the temporal variation over a day. Specifically, it explores how the introduction of parking fees on curb parking affects the demand for parking, as well as how it impacts the demand for parking at different weekdays and time of day.
- Finally, within the scope of IP-SUNTAN, a meta-analysis on parking price elasticities has been conducted. It summarizes the results of 50 studies concerning parking price elasticities in a structured way (Lehner & Peer, 2019). While most existing meta-analyses focus on one specific elasticity, Lehner & Peer (2019) derive expected ranges for the price elasticity of parking occupancy (EPO), the price elasticity of parking dwell time (EPV), and the price elasticity of parking volume (EPV). They estimate a seemingly unrelated regression model with cross-equation restrictions (SUR-CER) to account for correlations between the three elasticity types and to impose the restriction that the EPO equals the sum of the EPD and the EPV, which should hold under controlled conditions. So far, not much research has been conducted on the interplay between the EPO, the EPD, and the EPV, neither from a theoretical nor an empirical perspective.

Modelling reactions to changes in road pricing

One study explores the effects of the Stockholm and Gothenburg charging systems by (i) comparing the long-term price elasticity trends in Stockholm and Gothenburg, (ii) comparing the price elasticity observed when the peak charging levels were increased, and when the Stockholm system was extended, with those observed at the introduction of the charges, and (iii) understanding the difference in the peak and off-peak elasticity in the two cities. The elasticities are computed using the following formula, where D is demand and P is price, and X and Y refer to two different time periods, between which fare levels have increased:

$$E_{x \rightarrow y} = \frac{\text{LOG}(D_y) - \text{LOG}(D_x)}{\text{LOG}(P_y) - \text{LOG}(P_x)},$$

The elasticities are computed using traffic volume data as well as data on average trip costs (from the Swedish tax authority).

Analysis of stated preference data

Within the scope of IP-SUNTAN two stated preference datasets have been analysed. They can be used to enrich the available real-life data, and shed light on travellers' reactions to trade-offs that do not exist in reality:

- Various model that test whether travelers react differently to SP-experiments that have been framed as a short-run scheduling choice (change in a train departure time) vs. a long-run scheduling choice (permanent change in the train timetable). The data have been analyzed using multinomial logit models. Models containing error components, as well as different specifications of the utility function have been tested as well. See Peer & Börjesson (2018)
- For participants of the real-life experiment conducted in Vienna, a simple stated preference experiment has been set up, which contains a trade-off between travel time and cost. The resulting data have been analyzed using a simple multinomial logit model.

Analysis of satisfaction with crowding

Satisfaction with crowding among public transport passengers in Stockholm, and to what extent satisfaction with crowding can explain trip satisfaction has been explored. For comparison, the study also explores the satisfaction with and explanatory power of other attributes. The explanatory power of different attributes on trip satisfaction is modelled by applying a discrete ordered choice modelling. The model uses the Stockholm Customer Satisfaction Survey 2008-2016 and automatic location and passenger counts from vehicles operating in Stockholm in 2014 as inputs.

Assessing costs and benefits of low emission zones

A further study investigates the costs and benefits associated with a suggested low emission zone (LEZ) in Stockholm. A variety of data sources is used to establish the expected effects of the LEZ, among which are the following: visiting frequencies to the inner city by vehicles type, adaptations cost of refraining to go by car to the inner city (which were observed when the congestion charging levels were increased), forecast for annual average NOx concentrations, changes in prices on the second-hand car market (since the legal possibility to implement LEZ was introduced, the immediate effect was a price fall of second-hand diesel cars). These data allow for the comparison between costs and benefits associated with the suggested LEZ.

Conclusions

Numerous empirical analyses have been conducted within the scope of IP-SUNTAN. We have used a large variety of data sources ranging from individual level data from questionnaires, lab experiments, stated preference experiments, and real-life experiments to aggregate level data from car markets, passenger and parking counts and traffic volume measurements.

A particular focus has been on the evaluation of parking policies, which can constitute a useful alternative to road pricing schemes, as the latter tend to suffer from a lack of public acceptance and usually require higher investments in the monitoring technology.

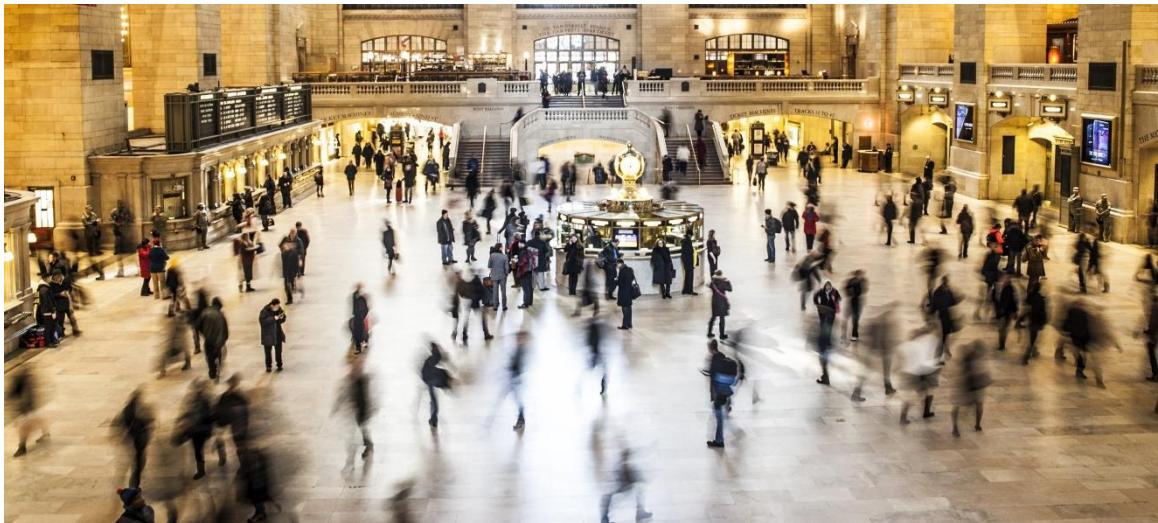
References

- ✓ Börjesson, M. and Kristofferson, I. (2017). [The Swedish Congestion Charges: 10 years on - and effects of increasing charging levels](#). CTS Working Paper 2017:2. Stockholm: Centre for Transport Studies.
- ✓ Börjesson, M. and Kristofferson, I. (2018). [The Swedish Congestion Charges: Ten Years On](#). Transportation Research A: Policy and Practice 107: 35-51.
- ✓ Brands, D., Verhoef, E. T., Knockaert, J., & Koster, P. (2019). [Tradable permits to manage urban mobility: market design and experimental implementation](#). Tinbergen Working paper TI 2019-007/VIII
- ✓ Kristoffersson, I. and Börjesson, M. (2018). The Swedish congestion charges: lessons learned. In Walker, J. (ed.): [Road Pricing Technologies: Examples, Economics and Acceptability](#). London: IET, pp. 363-386.
- ✓ Lehner, S. et al. (2018). Innovative pricing policies for commuting: a field experiment. Working Paper, available upon request.
- ✓ Lehner, S. et al. (2019). Participatory sensing data: the future of parking policy evaluation? Working paper, available upon request.
- ✓ Lehner, S., & Peer, S. (2019). [The price elasticity of parking: A meta-analysis](#). Transportation Research Part A: Policy and Practice, 121, 177-191.
- ✓ Lorenzo, H., Börjesson, M. and Daly, A. (2018). [Public Transport: One mode or several?](#) Transportation Research A: Policy and Practice 113:137-156.
- ✓ Peer, S., & Börjesson, M. (2018). [Temporal framing of stated preference experiments: does it affect valuations?](#) Transportation Research Part A: Policy and Practice, 117, 31
- ✓ Rubensson, A. and Börjesson, M. (2018). [Satisfaction with crowding in public transport](#). CTS Working Paper 2018:6. Stockholm: Center for Transport Studies.

Policy conclusions

The research carried out in IP-SUNTAN has substantiated the often defended but also often challenged claim that price incentives can offer a strong instrument to stimulate behavioural change in urban transportation. The research has, *inter alia*, revealed that:

- Road pricing strategies in Stockholm and Gothenburg has led to significant changes in behaviour
- A wide range of studies into parking behavior, surveyed by the Vienna team, confirm that travelers are sensitive to parking charges, and may for example respond by changing parking location, parking duration, or mode of transport and trip frequency



The extent to which pricing induces behavioural changes is by no means a natural constant.

- The Swedish road pricing case studies have revealed that elasticities – a measure for expressing behavioural responsiveness to prices – may change over time, and may do so in opposite directions (that is, the behavioural impact may increase or decrease over time)
- Behavioural change may (or will) also vary over sub-groups. The Vienna parking experiment suggests that selection effects of participants, if relevant in a certain application, may play a

strong role – confirming insights from earlier Spitsmijden projects in The Netherlands; but also that for examples visitors and locals may respond differently

- Behavioural change may also depend on the extent to which incentives are clearly explained to those drivers who are subject to these incentives. There is a fear that the sophisticated parking charge schedule tested in Vienna may have been too hard for participants to understand, limiting their responsiveness
- At the same time, travellers are very well capable of processing seemingly complex incentives. The experiment with tradable parking permits confirmed that travellers are perfectly capable of making the rational choices when applying this instrument in a serious-game setting; that is, a setting in which the choices made have real financial consequences
- Pricing policies naturally become more effective when more alternatives for behavioural change are offered. This was found to be true for parking policies in Vienna, but also for road pricing in Gothenburg (with less public transport options) versus Stockholm.

Pricing measures are often attractive from the societal cost-benefit perspective, in that these induce travelers to give up on those trips / vehicle kilometers / other units of consumption (including vehicle ownership and type) that bring them the smallest losses in benefits.

- Consistent with this notion was the finding that Low Emission Zones, in particular for passenger cars, may be a policy for which the societal losses (adaptation costs) may by far outweigh the societal benefits (the value of lower emissions).
- Another confirmation was obtained in the Randstad case study, which – through its game-experimental set-up – made clear that travelers indeed forego options with the lowest (lost) benefits when being confronted with financial incentives that make them change behaviour

The technical possibilities for applying sophisticated pricing are available and functioning.

- Applications with road pricing in Sweden confirm that the required technologies are robust, and – from a societal perspective – affordable in the sense that societal welfare benefits exceed the cost of toll collection
- The case studies in Vienna confirm that technologies for applying differentiated sophisticated parking charges can be applied using a variety of different technologies, including GPS-based technologies
- Also innovative pricing schedules that are based on tradable permit principles are relatively easy to apply in practice. The case study in the Randstad used an online market for tradable permits that functioned as desired, succeeded in bringing the equilibrium price to the theoretically expected level, and gave rise to very modest transaction cost and were considered to be relatively easy to participate in by the participants

Social acceptability is a key aspect for the political and societal feasibility of pricing measures.

- Even though a recurring pattern is that acceptability increases after implementation, acceptability is not a constant, and revisions of pricing systems may definitely raise new concerns over its acceptability, as was seen in Swedish cases
- The Randstad case study gives reason to believe that budget neutral price incentives such as tradable permit schemes, with an expected higher acceptance by avoiding structural money streams from travellers to the government, can indeed be put to practice, and seem to be both understandable and acceptable to participants
- Actual application of pricing measures may bring acceptance issues to the light that cannot always be predicted accurately from hypothetical questionnaire-based choice studies. One such example was the more limited impact of public transport crowding on trip satisfaction than what could have been expected from earlier valuation studies in Sweden

All in all, the study delivered new and more robust insights into the potential of pricing instruments in spurring behavioural change in urban mobility; and how this depends on the technical design including the differentiation of pricing and therewith the type of behavioural changes it seeks to stimulate, as well as the availability of alternatives. Societal acceptability is an important aspect, which is on the one hand hard to predict through its dependence on many factors, while at the same time this dependence gives room for optimizing policies also from this viewpoint. The technological advances enable full exploitation of such findings through an intelligent design of smart pricing measures. The study highlighted how experiments can really help in gaining insights into these important matters, in turn helping governments to design policies that better meet the triplet of criteria: effectiveness, efficiency, and acceptability.

In the media



[Voer maar in dan die zandloper op de weg](#) (Erik Verhoef, interview, NPO Radio 1, 2 February, 2019)

[So ganz stimmt es wohl nirgends, dass die Öffis immer pünktlich sind](#) (Stefanie Peer, WU Blog, January 2019)

[Rekeningrijden lijkt weer een stapje dichterbij](#) (Erik Verhoef, interview, Trouw, 30 January, 2019)

[Zo moeilijk is het niet, de files aanpakken](#) (Erik Verhoef, interview, De Volkskrant, 29 January, 2019)

[Bus oder Rad? Das ist hier die Frage](#) (Stefanie Peer in Mein Bezirk, January, 2019)

[Van 130 naar 120 is effectief, maar zet liever een kookwekker in je douche](#) (Erik Verhoef, interview, NOS.nl, 23 January, 2019)

[Weg in den Urlaub: Öffis überholen Auto](#) (Stefanie Peer, Kronenzeitung, January 2019)

[Österreicher nutzen lieber Öffis als Auto](#) (Stefanie Peer, Kleine Zeitung, January 2019)

[Transport en Provincie zien niets in tol op Brabantse snelweg](#) (Erik Verhoef, Algemeen Dagblad, 10 January, 2019)

[Luxemburg zet gratis OV in als tegen fileprobleem](#) (Erik Verhoef, BNR Nieuwsradio, 6 December, 2018)

['Gratis openbaar lost de files niet op'](#) (radio interview with Erik Verhoef, Bert op 5, 8 December)

[Files en rekeningrijden](#) (Erik Verhoef in Zondag met Lubach, 11 November, 2018)

[Helpt meer asfalt deze keer wel?](#) (Erik Verhoef in NRC, 13 November, 2018)

[Probeer het gedrag van automobilisten te veranderen om het fileprobleem op te lossen](#)
(Erik Verhoef in RTL Nieuws Half Acht, 30 October, 2018)

[Het aantal files zal alleen nog meer groeien. Wat te doen?](#) (Erik Verhoef, NOS Journaal, 30 October, 2018)

[Recept tegen verkeersinfarct: aan het eind van de file gas erop](#) (Erik Verhoef, Financieel Dagblad, 28 October, 2018)

[5 oplossingen voor verkeersproblemen die je nog niet kende](#) (Erik Verhoef, VU Magazine, 23 October, 2018)

[Parkeerrechten verhandelen werkt](#) (interview, Devi Brands, Verkeerskunde, 13 September, 2018)

[Een nieuw huis in de stad? Zeg dan maar dag tegen uw auto, of toch niet?](#) (interview with Erik Verhoef, De Volkskrant, June 25, 2018)

[Nederland fileland](#) (Erik Verhoef in Brandpunt+ tv documentary on ways to solve congestion, 12 June, 2018)

[Das Rad ist ein sehr platzeffizientes Verkehrsmittel](#) (interview with Stefanie Peer, Fahrrad Wien, April 2018)

[100 miljoen extra voor aanpak files](#) (comments of Erik Verhoef in NOS 8 o'clock news, 17 March, 2018).

[Duitse tolheffing tot zeker 2020 uitgesteld. 'Dat had je kunnen zien aankomen'](#) (interview with Erik Verhoef on BNR Nieuwsradio, 9 March, 2018)

[Meideinen op de spitsgolven](#) (interview with Erik Verhoef, Het Financieele Dagblad, 10 February, 2018)

[Meer asfalt: de weg van de minste weerstand](#) (interview with Erik Verhoef, Nederlands Dagblad, 6 January, 2018).

[Een dag file kost vele miljoenen, een dag sneeuw een veelvoud daarvan](#) (tv interview with Erik Verhoef, NOS Nieuwsuur, 11 December, 2017, from 6:13)

[Files kosten 15 miljoen euro per werkdag](#) (Erik Verhoef, NPO Goedemorgen Nederland, 20 November, 2017, from 15:00)

[Why Surge Prices Make Us so Mad: What Springsteen, Home Depot and a Nobel Winner Know](#) (Maria Börjesson about congestion charges in New York Times, 14 October, 2017)

[Actueel: Erik Verhoef over rekeningrijden](#), (Erik Verhoef, Vuurwerk, July, 2017)



[Österreichs Mobilität auf Klimakurs bringen](#) (interview with Stefanie Peer in VCÖ Magazin, June, 2017)



IP-SUNTAN

falls under the ERA-NET Cofund Smart Cities and Communities (ENSCC). ENSCC was established by the Joint Programming Initiative (JPI) Urban Europe and the Smart Cities Member States Initiative (SC MSI) in order to initiate a transnational joint call for RDI (Research Development and Innovation) proposals addressing new solutions in the urban field, and demonstrating the feasibility of their implementation. ENSCC is supported by the European Commission and funded under the Horizon 2020 ERA-NET Cofund scheme. Also SURF (Smart Urban Regions of the Future), which is part of VerDuS (Verbinden van Duurzame Steden - Connecting Sustainable Cities) is involved in sponsoring IP-SUNTAN.



PHOTOGRAPHY
Peter Valckx
Pixabay