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Transport Policy has no page charges

The Stockholm congestion charges—5 years on. Effects, acceptability and lessons learnt

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ABSTRACT

Congestion charges were introduced in Stockholm in 2006, first as a trial followed by a referendum, then permanently from 2007. This paper discusses what conclusions can be drawn from the first five years of operation, until mid-2011. We show that the traffic reduction caused by the charges has increased slightly over time, once external factors are controlled for. Alternative fuel vehicles were exempt from the charges through 2008, and we show that this substantially increased the sales of such vehicles. We discuss public and political acceptability, synthesising recent research and Swedish experience. We conclude that objective and subjective effects on the traffic system, as well as general environmental and political attitudes, formed the basis of the strong public support, while institutional reforms and resolution of power issues were necessary to gain political support. Finally, we briefly discuss implications for the transport planning process in general.

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1. Introduction

Congestion pricing has been long advocated by transport economists and traffic planners as an efficient means to reduce road congestion. Despite growing problems with urban congestion and urban air quality, and despite a consensus that investments in roads or public transit will not be sufficient to tackle these problems, cities have been reluctant to introduce congestion pricing.

In recent years, however, it seems that this is changing. London (2003), Stockholm (2006), Durham (2002), Milano (2008), Rome (2001) and Valletta (2007) have all introduced different forms of charging or permit systems to combat congestion and/or environmental problems. The Netherlands, Copenhagen, Budapest, Gothenburg, Djakarta and San Francisco are all considering congestion charges or planning to introduce them. The soon ubiquitous “value pricing” roads in the US are also examples of how congestion problems are now being tackled through pricing measures. New York, Manchester and Edinburgh have all tried to introduce congestion charges, and even if these attempts have been unsuccessful, it is a sign that congestion charges are being seriously considered to a greater extent than a decade ago.

The congestion charges in Stockholm have attracted enormous attention worldwide. Obviously, the opportunity to gauge the effects of congestion charges on traffic, congestion levels and travel behaviour has attracted great interest. Perhaps even more interesting is how the congestion charges survived a heated and complicated political and legal process, including a referendum initially forced through by opponents to the charges. The Stockholm charges went from “the most expensive way ever devised to commit political suicide” (to quote the then-secret feelings expressed by the Head of the Congestion Charging Office¹) to something that the initially hostile media eventually declared to be a “success story” (e.g. Dagens Nyheter, June 22, 2006).

The Stockholm charges were introduced in January 2006, at first as a six month trial. During the trial, an extensive monitoring and evaluation programme was carried out, and many types of analyses based on these data sets have been published previously (references are given in Section 2). The two most important findings were that the charges did indeed cause substantial traffic reductions, leading to reductions in congestion and travel time variability, and that the public opinion changed from hostile to a small majority in favour of the charges. The aim of this paper is to explore how these effects have developed over time, and hence whether the conclusions based on the observations from the trial period stand the test of time. Hence, we focus on whether the

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¹ Quote Gunnar Söderholm, social-democratic head of the Congestion Charging Office during the trial, when (after the trial) describing the local Social Democrats' feelings when the national Social-Democratic government more or less forced the congestion charges onto the local Stockholm party district.

traffic reduction has persisted, whether congestion levels have stayed on a lower level, and how public and political acceptability has developed over time. The traffic effects are central, since they are the main driver of other benefits, such as improvements of local air quality, travel time reliability and greenhouse gas emissions. The increased public and political acceptance has been crucial for the survival of the charges since the trial. To some extent we will also discuss how the introduction of road user charges as a revenue source has affected the national infrastructure planning process. In the evaluation programme of the Stockholm trial, a large number of other effects were studied, including effects on businesses and retail, and location of households and firms. In most cases effects these were found to be small, and they have therefore not been studied further. Section 2 gives a brief description of the charging system, its history and references to previous studies.

There has been some apprehension that the effects of the charges will attenuate over time, either because drivers "get used to the charges" and hence do not react to them anymore, or because the freed-up road space will be filled up by new groups of drivers, returning the amount of congestion to the same levels as before the charges. This is the topic of Section 3, where we explore the long-term effect of the charges on traffic volumes.

Section 4 discusses the significance of the clean car exemption and the importance of different incentives for the sales of clean cars.

Section 5 is devoted to public and political acceptability. We draw from a number of sources to explain and discuss the current opinion on congestion charges, and the political context of the charges. We also discuss how the possibility to introduce road user charges has affected the national infrastructure planning process.

2. An overview of the Stockholm congestion charging system

The Stockholm congestion charging system consists of a toll cordon around the inner city, thereby reducing traffic through the bottlenecks located at the arterials leading into the inner city. The cost² of passing the cordon on weekdays is € 2 during peak hours (7:30–8:30, 16:00–17:30), € 1.5 during the shoulders of the peaks (30 min before and after peak period) and € 1 during the rest of the period 6.30–18.30. The charge is levied in both directions, implying that a return trip during peak hours costs € 4. The maximum total charge per day is € 6.

The system was introduced on a trial basis during the period January 3–July 31 2006. The trial period was followed by referendums in the City of Stockholm and in about half of the neighbouring municipalities, originally pushed through by opponents to the congestion charges. The referendum in the City of Stockholm itself resulted in a majority for keeping the charges, but based on the total number of votes in the County of Stockholm the majority of the voters were against the charges. However, adding all the votes in the County produces a result that is negatively biased compared to the overall public opinion in the County of Stockholm, because not all municipalities arranged a referendum. The public opinion in the municipalities that arranged a referendum was in general more against charges than the public opinion in the entire County. In the end, the new Liberal-Conservative government decided to reintroduce the congestion charges, earmarking the revenues for road investments but as part of a more comprehensive, partially government-funded transport investment package including both road and transit investments. The congestion charges were reintroduced in August 2007.

² Throughout the paper we have converted SEK to Euro using a conversion rate of 10 SEK/€.

The charging trial and the results of the monitoring programme have been described in detail elsewhere. An overview of the effects can be found in (Eliasson et al., 2009) and (Eliasson, 2008), where the latter also discusses the main lessons from the trial in terms of design, effects, acceptability and political process. (Eliasson, 2009a) provides a cost-benefit analysis of the congestion charges, based on effects measured during the trial. A detailed account of the political process can be found in (Gullberg and Isaksson, 2009), and experiences from the design and evaluation processes are described in (Eliasson, 2009b). (Karlström and Franklin, 2009) and (Franklin et al., 2010) analyse behavioural responses and equity effects. (Daunfeldt et al., 2009) investigate whether the retail sector was affected by the introduction of the charges, with a focus on the apprehension that retail in the inner city may be hurt, but finding no such effects. (Kottenhoff and Brundell Freij, 2009) discuss the role of the public transport system for the effects and acceptability of the charges, and in particular the introduction of a number of new bus lines in anticipation of the introduction of the charges. (Isaksson and Richardson, 2009) analyse the strategy to create legitimacy for the charges, while (Gudmundsson et al., 2009) examine how decision support systems were used. (Winslott-Hiselius et al., 2009) provide an early analysis of the public attitudes, and also analyse the media coverage. (Brundell-Freij et al., 2009) and (Eliasson and Jonsson, 2011) provide analyses of the developments of the public attitudes up to late 2007, focusing on what factors explain differences and changes in public acceptability.

3. Long-term adaptation effects

The charges had a substantial effect on traffic volumes, and drivers have adopted many different adaptation strategies. In this section we explore the extent to which the behavioural adaptation has changed over time.

3.1. Traffic volumes across cordon

Fig. 1 shows the average number of passages across the cordon per weekday (6 am to 7 pm) for each month from January 2005 through September 2010. Corresponding numbers are presented in Table 1.

For each year, Fig. 1 exhibits a systematic seasonal variation, with volumes increasing throughout spring, a minimum in July and August (summer holidays) and stable volumes during the rest of the year.

3.1.1. The trial: Immediate reaction, slightly diminishing over time

Fig. 1 shows that the charges had a substantial effect on car driver behaviour from the first day of introduction in January 2006. This effect, as reflected by relative difference to the reference level (2005), was –28% in January. During the following months, volumes across the cordon increased successively, from just over 3,00,000 per day in January, to almost 4,00,000 per day in May. Some observers in the media and the general public interpreted this increase (large enough to be noticed by the naked eye) as a sign that the charges were successively losing their effectiveness. To the informed analyst, however, it was evident that the increase was mainly due to seasonal variation, similar to the reference figure for 2005. Nevertheless, the figures indicate that road users overreacted initially (with an estimated effect of –28% in January and –23% in February), but successively found more stable adaptation strategies (20–22% in March–June).

The adaptation strategies were different for different trip purposes. 24% of commuting trips by car across the cordon disappeared; nearly all of these switched to transit – only 1% switched route to avoid the cordon. 22% of discretionary trips by car across the cordon disappeared. Here, the main adaptation strategies seem to

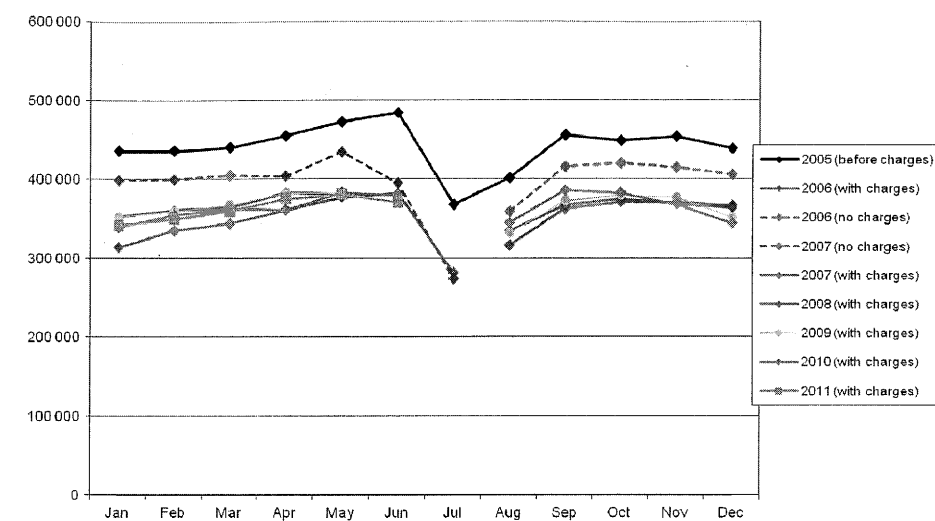


Fig. 1. Average number of passages across cordon (weekdays 6–19). 2005–2011 (For months when charging was applied, the numbers in Fig. 1 are those that were registered by the charging system, and therefore very precise. For other periods, numbers are to some extent estimated based on calculations from other traffic counts. Comparability between years for corresponding months is somewhat compromised by calendar effects: a number of national and school holidays alternate between months.)

Table 1

Reduction in traffic volumes over cordon (weekdays 6–19) compared to reference (2005). Figures in italics represent period without charging (Aug 2006–Jul 2007).

Compared to 2005	Jan(%)	Feb(%)	Mar(%)	Apr(%)	May(%)	Jun(%)	Jul ^a	Aug(%)	Sep(%)	Oct(%)	Nov(%)	Dec(%)	Average(%)
2006	-28	-23	-22	-21	-20	-21	-24	-11	-9	-6	-9	-7	-21 (Mar–Jun)
2007	-9	-8	-8	-11	-8	-18 ^b	-26 ^b	-21	-20	-17	-18	-17	-19 (Aug–Dec)
2008	-19	-17	-17	-16	-19	-22	-	-17	-19	-16	-19	-17	-18 (excl. Jul)
2009	-19	-18	-16	-16	-19	-24	-	-17	-18	-15	-17	-20	-18 (excl. Jul)
2010	-22	-1	-18	-21	-19	-22	-	-14	-15	-15	-19	-22	-19 (excl. Jul)
2011	-22	-20	-18	-17	-19	-23	-	-	-	-	-	-	-20 (excl. Jul)

^a From 2008 onwards the congestion charging system is not operating in July, and hence there are no measurements.

^b The figures for June and July 2007 are affected by major roadworks.

have been changing destinations and decreasing trip frequencies. Commercial traffic (deliveries, business trips, freight traffic etc.), decreased by approximately 15%, adapting by switching route or by trip chaining (Eliasson, 2008), (Franklin et al., 2010).

3.1.2. The in-between period: traffic increased, but some effects of charging remained

From 1 August 2006, the charges were no longer in effect. Traffic volumes immediately rebounded almost to the same level as before the charges – but not quite. A residual effect remained even after the charges had been abolished. From August 2006 to August 2007, i.e. between the end of the trial and the reintroduction of the charges, traffic volumes remained 5–10% lower than in 2005.³

Why did some drivers not return to their old habits in the period when no charges were levied? Other factors, such as fuel prices, changed too little to cause such a relatively large traffic decrease. Apparently, some car users developed new travel habits during the trial – habits persisting even after the charges were abolished. It is impossible to certify the cause-effect relationship underpinning our observation of a residual traffic decrease. One hypothesis is, however, that some drivers were pressed by the charges to search for travel alternatives, and found such alternatives that were indeed more suitable for them, once they were tested. Another hypothesis is that some drivers were forced to

³ The exact size of the residual effect is uncertain, since data from this period are less reliable due to roadworks and technical problems with the measurement equipment.

invest in alternative travel options (e.g. buying a motorcycle), which could not be changed back without new transaction costs. (Further discussions of "hysteresis" effects can be found in (Goodwin, 1977) and (Dargay, 1993).)

3.1.3. Permanent charges: Immediate effects, slight volume changes due to external factors

The charges were reintroduced in August 2007. Compared to the old reference (2005), the introduction of permanent charges had the same effect on traffic volumes as they had had during the trial: in August 2007 there were 21% fewer passages across the cordon (during charging hours) than in August 2005.

During the first year of permanent charges, volumes over the cordon increased slightly. During 2008–2009, traffic across the cordon remained on average 18% below the 2005 level. This was apparently substantially smaller than the –21% at which relative difference had stabilized at the end of the trial. During 2010 and 2011, however, traffic decreased again slightly to –19% and –20% (compared to 2005), respectively. As will be shown in the next section, these changes can be explained by external factors influencing traffic levels and the real-term charge level.

3.2. Have the effects attenuated over time?

The observed increase of cordon volumes described in the previous section can at first sight be interpreted as indicating that the effects of the charges attenuate over time, in other words that the price elasticity of traffic decreases over time. However, this

Table 2
Reduction of traffic across the cordon compared to 2005, adjusted for external factors and exemptions, 2006–2011.

All figures are relative to 2005	2006(%)	2007(%)	2008(%)	2009(%)	2010(%)	2011(%)	elasticity
Change in total employment in the county	1.8	4.2	7.7	8.4	10.0	11.6	0.85
Fuel price (95 oct), real prices	2.4	1.0	5.1	1.3	7.7	14.8	-0.3
Private cars per employed person	-0.5	-1.0	-3.2	-3.7	-4.1	-4.6	0.5
Total effect on traffic volume	0.6	2.8	3.2	4.7	3.9	2.9	
Traffic reduction from charges, compared to 2005 (from Table 1)	-21.0	-18.7	-18.1	-18.2	-18.7	-20.1	
Traffic reduction adjusted for external factors (from above)	-21.4	-20.	-20.7	-21.9	-21.7	-22.3	
Exempt traffic (share of all passages)	28	24	26	29	2	25	
Reduction of non-exempt traffic, adjusted for external factors	-29.7	-27.5	-28.1	-30.7	-29.	-29.8	

interpretation does not take into account two factors: first, that several external factors such as population growth affect traffic volumes, and second, that other factors such as inflation and changes in deductibility regulations have changed the charge level in real terms. In this section we will compare the long-term and short-term effects of charging, taking these factors into consideration. Note, however, that as time passes, it becomes increasingly difficult to separate the effects of the congestion charges from other external factors. Despite this caveat, it is obviously important to know whether long-term effects are very different from short-term effects. If apprehensions are true that the effects of the charges indeed “wear off”, then this would be a considerable problem for any price-based transport policy.

There are two reasons why the long-term effects might be smaller than the short-term effects. First, there might be a “acclimatisation” effect: after a while, people might get used to the charge and consider it less important when making their travel choices. This effect could be especially important if it is, at first, a little difficult to pay the charge—and the extra “cost” of actually making the payment might decrease over time. Second, the freed-up road space may induce new traffic—travellers with high values of time, or travellers making car trips not crossing the cordon.

There are also a number of reasons why the long-term effects might be larger than the short-term effects. There are more possibilities to adjust travel behaviour in the long run. Over time, people continually reorganise their lives, relocate place of residence or work, become familiar with new destinations or change other habits, and in this process they will take the permanent charges into account. The fact that the charges were first implemented as a “trial” might also have implied smaller behavioural effects in the short run because travellers decided to wait it out.

First, external factors influencing traffic volumes will be adjusted for. 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 (Eliasson, 2009a). Its explanatory variables are employment in the Stockholm 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 is estimated to -0.3, which corresponds well with what is usually found in the literature (see for instance (Goodwin et al., 2004)). Table 2 shows the traffic reduction after adjusting for external factors.

Table 2 also shows how the share of exempt traffic has varied across years. In 2006, taxis were exempt, but the taxi exemption was abolished when the charges reintroduced in 2007. On the other hand, the share of exempt “clean cars” has grown considerably, from 2% in 2006 to a peak at 14% in 2009. Clean cars bought after 2008 are not exempt, so the share of exempt clean cars have

decreased to 10% in 2011. The “clean car exemption” is analysed in detail in the next section.

The last row of Table 2 shows the reduction of non-exempt traffic, adjusted for external factors. This is the “charge effect” that can be compared across years. In 2006, it was nearly 30%, dropping to around 27% in 2007, then increasing to nearly 31% in 2009, finally decreasing slightly again to just below 30% in 2010–2011. This is a different variation pattern than what appears from the non-adjusted traffic volumes, but it is still true that the variations are relatively moderate: the traffic reduction has remained remarkably stable over time.

To calculate how the elasticity has developed over time, it is also necessary to consider that the charge has changed in real terms over time. First, inflation has reduced the charge with about 2% per year on average. Second, in 2007 the charges became tax deductible for commuters provided certain requirements are met.⁴ This applies to approximately 8% of all car trips across the cordon, according to a travel survey (RES2005–2006). The tax deductibility represents a 60% reduction of the charges. Third, regulations for company car costs have been changed. A “company car” denotes a company-owned car used by an employee for both work-related and private purposes. Company cars, which constitute 23% of all vehicles crossing the charging cordon, receive at least a 60% reduction of the congestion charge, since the drivers are now allowed to pay the charge from their gross salary. About 20% of all company cars pay no charge at all. During the trial, no such discounts were received. A fairly large share of company cars are “clean cars” and hence exempt, though.

The elasticity is calculated as $\epsilon_i = (\ln(f_i/f_1)/\ln(p_i/p_1))$, where f_i and f_1 are the non-exempt volumes, adjusted for external factors, and p_i and p_1 are total travel costs in real terms (adjusted for inflation, deductibility etc.). Index 1 is 2005 and index i represents the following years ($i=2006, 2007, \dots, 2011$). To get an estimate of the average total travel cost, we note that the median length of trips crossing the cordon was 13 km,⁵ both before and after the trial in 2006, according to travel surveys carried out before and during the trial. Controlling for increases in fuel price, the average marginal driving cost has stayed constant at €0.15/km. Hence, the median trip cost excluding the charge is € $13 \times 0.15 = € 1.95$ Table 3.

The last row compares the elasticity across years. It has increased from -0.70 in 2006 to an apparently stable value of around -0.85 in 2009 and onwards. It may be too early to tell if this is really the “long-term” value, although it seems likely. But the most important conclusion is that there are no signs that the effect of the charges is wearing off. On the contrary, it has increased somewhat over time.

⁴ The trip must be longer than 5 km and the commuter must save at least one hour compared to public transit one way; or, the commuter must need the car for work purposes.

⁵ For trips crossing the cordon twice, trip length is divided by two in this calculation.

Table 3
Changes to the charge in real terms, and changes in elasticity across time, 2006–2011.

	2005(%)	2006(%)	2007(%)	2008(%)	2009(%)	2010(%)	2011(%)
Inflation (compared to 2006)			2.21	5.77	5.43	6.77	9.01
Company cars (share of all cordon passages)		23	2	23	23	23	23
Clean cars (share of all cordon passages)		3	9	12	14	12	10
Company cars that are not “clean cars”		21	16	14	12	13	15
Real charge reduction factor due to company cars			0.89	0.90	0.92	0.91	0.89
Real charge reduction factor due to tax deductibility			0.95	0.95	0.95	0.95	0.95
Real charge adjustment factor (total)			0.82	0.81	0.83	0.80	0.78
average charge, real terms		1.28	1.06	1.04	1.06	1.03	0.99
average total trip cost, real terms	1.95	3.23	3.01	2.99	3.01	2.98	2.94
Reduction of non-exempt traffic, adjusted for external factors (from table 2)		-29.7	-27.5	-28.1	-30.7	-29.8	-29.8
elasticity		-0.70	-0.74	-0.77	-0.85	-0.83	-0.86

This is consistent with the observation that there are more adaptation mechanisms available in the long-term than in the short-term. This result is in correspondence with that of (Goodwin et al., 2004), who note that price impacts tend to increase over time as consumers have more options.

A considerable share of all traffic is commercial traffic, including taxis (which are non-exempt as of 2007). Taxi make up 8% of the cordon passages, business trips 9%, and distribution and other heavy traffic 18%. Presumably, this traffic is less cost sensitive than private trips. If we do the extreme assumption that only private trips are affected by the charges, the charge elasticity becomes -1.27 in 2006, increasing to just below -1.9 in 2009–2011.

Note that these elasticities are neither comparable with the usual cost elasticity of car traffic, nor with the fuel price elasticity of car traffic. Since fuel costs make up around half the marginal cost of driving, the cost elasticity of car traffic is around twice the fuel price elasticity. The elasticity of traffic across the cordon with respect to the charge is higher, since there are more adaptation mechanisms available, such as changing route, destination or time of travel.

An interesting question is how the effect of the charges will develop in the future. If the long-term adaptation already has taken place we would expect the long-term elasticity to remain roughly constant from now on. Since the traffic flow increases due to external factors, primarily increasing population in the county, the charge must, however, increase to keep the traffic flow at the present level. The employment in the county is projected to increase by around 2 per cent per year, yielding a traffic growth of around 1.7% per year (assuming, for the sake of argument that car ownership and fuel prices do not change). The charge must then increase $\exp(\ln(1 - 1.7\%)/-0.85) - 1 = 2$ per cent per year in real terms to keep the traffic flow across the cordon constant.

3.3. Traffic volumes on other links (not crossing the cordon)

Next, we discuss how the traffic volumes have developed inside the cordon, on important bypasses and links outside the cordon. For the inner city, a key issue is whether we can identify any trend increase in traffic volumes, indicating that the road space freed-up by the charges generates new traffic.

The traffic volumes in the inner city were 8%–9% lower during the trial (depending on type of street) compared to the levels before the trial, which also imply improved local air quality. Traffic volumes have remained stable since the charges were introduced.

Traffic between the northern and southern part of Stockholm can avoid the charges by using the bypass E4/E20 west of the inner city. Some of this traffic will also use the southern relief road, Södra länken. These relief roads were already congested before the implementation of congestion charges and there were concerns that congestion would become even more severe when

the charges were introduced. However, the traffic volumes have remained relatively unaffected by the charges.

Traffic on relief roads, bypass E4/E20 and Södra länken, have only increased by approximately 5 per cent since 2005, which can be explained by an increase in employed inhabitants (assuming the same traffic increase applying to traffic crossing the cordon calculated in the previous section). Södra länken shows a similar pattern, although the percentage increase is somewhat larger. The higher increase is largely due to higher population growth in the relevant catchment area than in the Stockholm County and to ramp-up since the link opened in 2004. However, traffic volumes on Södra länken fell in 2008 (down by 4.6 per cent, compared to 2007), for the first time since the road opened in late 2004.

Fig. 2 visualises the trend increases in traffic volume on bypass E4/E20 and Södra länken. Interestingly, the figure does not indicate when the congestion charging system was introduced (January 2006), turned off (August 2006), and then reintroduced (August 2007), which confirms the conclusion that the charges have no large impact on the congestion levels on the orbital roads.

Indications that charges have no great impact on the congestion are also found for other links outside the cordon. The trend in traffic volumes has also been followed up for some particular links for which there was concern that congestion would increase. However, these links did not suffer from any significant increase in volumes during the trial (April 2005–April 2006), and the traffic increase since then has been limited.

In summary, the cordon system in Stockholm does not, therefore, seem to have generated any severe second-best problems in either the short or long-term perspective.

3.4. Journey times and congestion

Since April 2005, the primary data source for travel times has been the travel time measurement camera system, operating until November 2008. Previous analyses of these display how travel times decreased dramatically during the trial in 2006, especially on the approach roads but also in the inner city. When the permanent system was introduced again in 2007 the level of congestion decreased to approximately the same levels as during the trial (Eliasson, 2008).

In 2008, the cameras were not maintained and functioning as well as in previous years, and there are only data for a few links, making the comparison between years less reliable and representative. Still, measurements taken from all weekdays for approximately six consecutive weeks in October 2007 (after the charges had been reintroduced) and in October 2008 provide some evidence that the level of congestion has remained virtually unchanged since the congestion charges were reintroduced; see Fig. 3. There is no data for 2009.

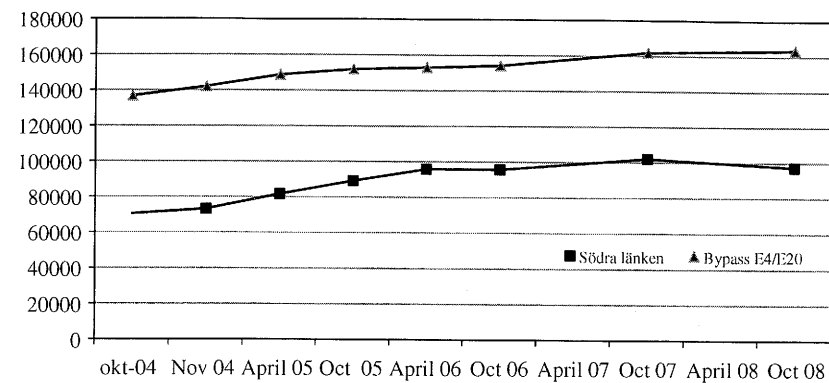


Fig. 2. Traffic volumes from 2004 to 2008 on bypass E4/E20 and Södra länken, free of charge.

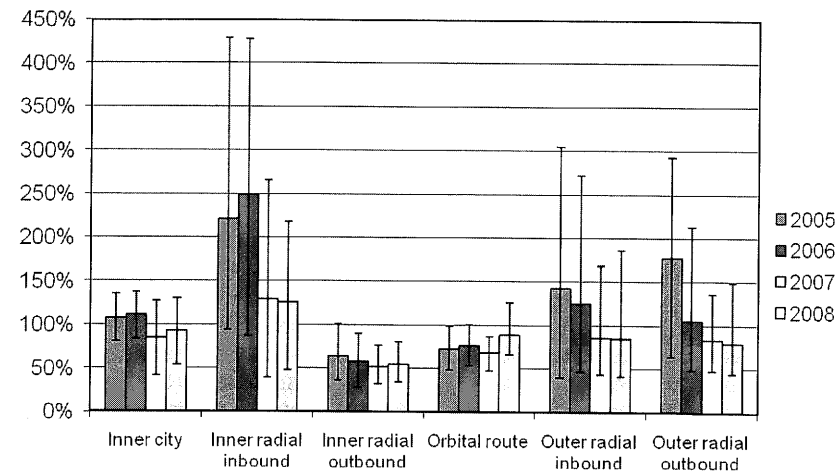


Fig. 3. Relative increase of travel times for four different types of links. 0% corresponds to free-flow travel time. The coloured bars show average travel times while the "error bars" indicate the worst decile and the best decile of the travel times distribution.

4. The exemption for alternative fuel vehicles

There are several incentives in Sweden to promote the sales of "clean vehicles". Fuel cost is kept low due to the fact that there is no tax on renewable fuels, and clean vehicles are exempt from parking charges in some cities. In addition to these incentives, it was decided that alternative fuel vehicles were to be exempt from congestion charges in Stockholm. The alternative fuel car exemption will now be phased out. Since January 1 2009 alternative fuel vehicles registered after this are no longer exempt, while alternative fuel cars registered before this date are exempt until 2012.

Two key questions emerge from the exemption of alternative fuel vehicles: Did this exemption have any effect on the sales of alternative fuel vehicles, and what effect did it have on congestion levels? This section aims at addressing these questions.

At the time of the trial, "clean cars" were defined in Sweden as alternative fuel vehicles, including ethanol, biogas (CNG), hybrid and electric cars. Since the congestion charging trial, the definition of clean cars has changed and now includes petrol and diesel cars emitting less than 120 g CO₂ per km. Still, when congestion charges were introduced permanently, the old definition of clean cars was kept.

4.1. Effects of the alternative fuel car exemption on sales

During the trial in the spring of 2006, 2% of passages were alternative fuel vehicles. In December 2008 the share of alternative fuel vehicles had increased to 14%. In 2009, this share did not decrease appreciably. The exemption from congestion charges

was not the only incentive for alternative fuel vehicles – there have been several other local and national incentives to increase the market share of clean vehicles (the new definition also includes low-CO₂ emission petrol and diesel cars). In the city of Stockholm, free residential parking for clean vehicles was introduced in 1997. Measures applying to the national level have included no tax on renewable fuels, and an obligation for each petrol station to sell at least one type of alternative fuel, a special queue for clean taxis at Arlanda airport, lower value of fringe benefits for tax assessment for clean company cars and a national purchase subsidy for clean vehicles of € 1 000.

In 2008, sales of clean cars grew at a record pace in comparison to other European countries. One third of all cars sold in Stockholm and a quarter of all cars sold in Sweden were clean cars. Fig. 4 shows the development of clean car sales from 2001 to September 2009 for Stockholm and Sweden (The sales after September 2009 are not yet available). The sales of alternative fuel cars have increased by 23% from 2005 to 2008 in the Stockholm County. Note that the "Low-CO₂ cars" were not exempt from charges.

As can be seen in the figure, the sales of clean cars were greater in Stockholm than in Sweden in 2006 and 2008. In 2007, when charges were in place less than half of the year, the sales rates were approximately the same in Stockholm and Sweden, indicating that the local incentive of congestion charges exemption had an effect on the sales of alternative fuel cars in Stockholm.

In order to obtain a more detailed understanding of the mechanism behind the clean vehicle market, the Environment and Health Administration in Stockholm has studied the impact of different incentives on clean car sales. With statistical analyses

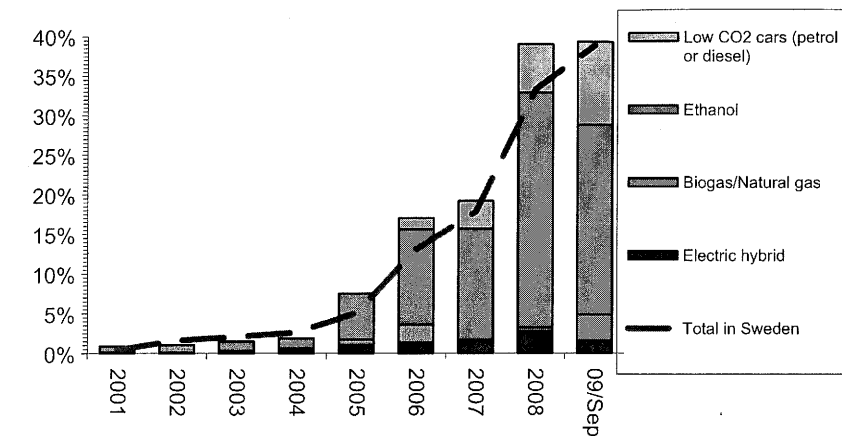


Fig. 4. Share of clean car sales relative to total sales of new cars, 2001–2009 (2009 sales refer to January–September). The bars show the sales in Stockholm, while the line shows the sales in Sweden as a whole (including Stockholm).

they have quantified the importance of different factors/incentive. (City of Stockholm Environment and Health Administration, 2009). Two types of statistical analyses were carried out, producing consistent results: one time series analysis and a cross-section analysis. The time series analysis used monthly sales data and combined it with dates of introduction of different incentives and the development of fuel prices. This allows us to verify the importance of an incentive. The cross-section analysis used information about the share of clean cars per municipality and how the incentives varied across these municipalities. With this analysis, it is possible to verify whether the share of clean vehicles depends on a local incentive. The study was carried out to investigate the market in Stockholm County.

Both studies showed that the most important incentive was the exemption from congestion charges. The lower cost for alternative fuels (compared to conventional fuels) had a similar positive effect on sales. The free residential parking for clean vehicles had a lower impact on sales. The reduction of € 1 000 on the purchase price has mainly affected the sales of small city cars with low-CO₂ emission (which are not exempt from the congestion charges).

The largest proportion of sold clean cars was company cars: 91% (about 60% of all new sold cars in Sweden were company cars). This is perhaps surprising, since one would expect that drivers with privately owned cars would be more cost sensitive. There are two likely explanations for this. First, handling the charge payments for each passage for each vehicle involves quite an extensive administrative load for a company. Buying an alternative fuel car alleviated this administrative burden. Second, the company was able to show their customers that they accepted their environmental responsibility.

The increased share of alternative fuel vehicles has only contributed to a minor increase in traffic volumes across the cordon, because this segment of drivers is not as price-sensitive as the average drivers. Most alternative fuel vehicles are taxis (2.6% out of 14%), company cars or cars in commercial traffic (8.2% out of 14%). Moreover, for company cars, the tax-deduction regulation would apply if alternative fuel vehicles had not been exempt. Only 3.2% of cars crossing the cordon are private motorists driving an alternative fuel car.

Since 2009 there is now a successive phasing-out of the exemption of alternative fuel vehicles. However, because drivers of exempt cars are less price-sensitive than on average, the impact on traffic volumes is rather limited. Taking away the exemption for alternative fuel vehicles, however, increases revenues.

5. Political and public acceptability

Congestion charging is met with public resistance in most cities, and Stockholm was no exception. The resistance became even fiercer because of the way congestion charges were introduced. The leader of the Stockholm Social Democrats, Annika Billström, had promised before the election in 2002 that there would be no road pricing in Stockholm during the next election period. But after the general election, the Green party forced through a "full-scale trial with congestion charges in Stockholm" as a condition for supporting a Social-Democratic national government. The Social Democrats on the national level leaned on Mrs. Billström to accept a charging trial, in order not to jeopardise the formation of a Social-Democratic government. This breach of promise coloured the debate about the congestion charges long after the decision to carry out a trial, even turning many potential supporters against the charges.

Among the many surprising experiences in Stockholm, this is arguably the biggest: how the charges managed to survive an extremely heated process and gain both public and political support to the extent that the existence of the charges is now virtually a non-issue. In this section, we will discuss how this happened and what general lessons can be learnt. First, we give a brief review of how public and political opinions have evolved. The following sections discuss public and political acceptance. Finally, we discuss the consequences for transport investment planning in general.

5.1. A brief review of opinion and politics

When the decision was made to carry out a "congestion charging trial" in Stockholm, it was met with great resistance – although not compact. In the spring of 2004 and the spring of 2005, 40% of Stockholm citizens stated that they would "probably" or "most likely" vote yes to permanent congestion charges. Support fell, however, once the start of the trial approached. Right before the start of the trial, support had fallen to 36%, with the "most likely yes" group falling the most. Once the trial started, however, support increased to 52%. The media image also changed once charges were in place, from intensely critical to, in many cases, very positive. The percentage of trial-related newspaper articles with a positive angle increased from 3% in the autumn of 2005 to 42% in the spring of 2006, while the share of negative newspaper articles was almost halved from 39% to 22% (Winslott-Hiselius et al., 2009). The trial ended on 31 July, 2006, and was followed by a referendum in September at the same time as

general and local-government elections were held. Excluding blank votes, 53% of Stockholm citizens voted to keep the charges. After the election, the centre/right coalition gained power both at the national level and in the city of Stockholm. The centre/right coalition in Stockholm had opposed the congestion charges, but had promised to follow the outcome of the referendum, so they had to ask the national Government to reintroduce the charges permanently. After a few weeks of consideration, the new centre/right Government said it would do so, but as part of a broader package of transport investments in Stockholm, to be negotiated. The revenues from the congestion charges were earmarked for road investments. On the other hand, the investment package also contained major rail investments, but these were claimed to be financed by other sources of funding. After the decision to include the charges in an investment package, no political parties proposed abolishing them anymore.

The charges were reintroduced permanently in August 2007, although the negotiation over revenue use was not settled until late 2007. A poll in December 2007 showed a 66% support for the charges. A poll in August 2009 phrased the question as "Do you think the congestion charges should be decreased, increased or stay as they are?". 56% wanted to keep them as they were, 18% wanted to increase them and 26% wanted to decrease them. Although the formulation of the question makes it hard to compare it with previous polls, the outcome can reasonably be interpreted as a 74% support for the charges. A poll in May 2011, encompassing most of Stockholm county, showed a support for the charges of over 70%.

5.2. Factors affecting public acceptability

So what has caused this unexpected and (to our knowledge) unique public support? More precisely, what caused the opinion to change? Several authors have argued that acceptability of road pricing is likely to increase with familiarity (e.g. (Jones, 2003)), and this is supported by empirical experience. For Norwegian experience, see (Tretvik, 2003), (Odeck and Bråthen, 1997), (Odeck and Bråthen, 2002), (Odeck and Kjekreit, 2010); for London, see (Banister, 2003) and (Georgina Santos, 2008). Several reasons for this phenomenon have been suggested, all of which may contribute to some extent.

1. Benefits may turn out to be larger than anticipated. Several authors have noted that a major reason for the resistance to congestion charges is that they simply will not work (see e.g. (Jones, 2003), and (Bartley, 1995)). If they in fact prove to

be effective in the sense that congestion decreases, then attitudes may grow more positive.

2. The downsides of charges – increased travel costs and/or changes in travel behaviour – may prove to be not as bad as expected. Once the charges are in place, many people may discover that the charges do not in fact affect them as much as they had thought. Stockholm evidence of this phenomenon is reported in (Henriksson, 2009).
3. Once the charges are decided, resistance may decrease due to the psychological effect known as cognitive dissonance (Festinger, 1957), a phenomenon that can be simply summarised as "accept the unavoidable". In other words, once the charges are in place, it is less worthwhile spending energy on opposing them. (Schade and Baum, 2007) show that respondents in an experiment are more positive to charges if they have been led to believe that charges are certain to be implemented.
4. Familiarity with road user charging may reduce the general reluctance towards pricing a previously unpriced good. There is evidence that "people in many cases do not like prices as an allocation mechanism" (Frey, 2003); see also (Jones, 2003). But once familiar with the concept that road space is in principle a scarce good that can be priced – much like parking space or telecommunication capacity – this reluctance may tend to decrease.

While the first two reasons above are related to the objective effects of the charges (decreased travel times, increased travel costs etc.), the second two are related directly to individuals' attitudes. Attitudes, behaviour, objective effects and how effects are perceived are all interrelated, as shown in Fig. 5 (from (Eliasson and Jonsson, 2011)):

The objective effects of the charges cause two types of perceived effects. First, there are direct effects on the individual, such as changed travel costs and travel times. Naturally, these effects depend on the individual's travel behaviour. Second, there are "social" effects, system level effects that do not directly affect the individual. It is known, however, that not only direct, individual effects but also such "system" or "social" effects affect attitudes (Jaensirisak et al., 2003); (Bamberg and Rölle, 2003), (Jones, 2003). Attitudes also depend on individual characteristics and preferences, such as political views, environmental concerns, or acceptance of pricing as a policy instrument. Finally, attitudes also affect the perception of system effects, creating a mutual dependence: a respondent with a positive attitude to charges is more inclined to believe that the charges have had beneficial

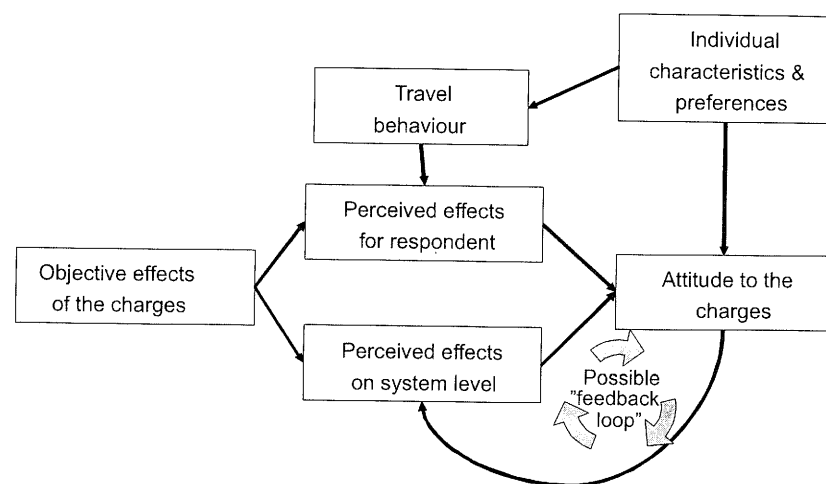


Fig. 5. Interactions between attitudes, travel behaviour and the objective effects of the charges.

effects, and vice versa. This may cause a "feedback loop" between the attitudes and the perceived system effects, where information that strengthens already held attitudes is given more weight, thereby reinforcing the attitudes, in a positive or a negative direction. As (Rienstra et al., 1999) conclude, claiming that congestion charging is ineffective can be a strategic response to justify a negative attitude towards charging.

Three recent papers have investigated explanatory factors behind the positive opinion in Stockholm (Hårsman and Quigley, 2010), (Eliasson and Jonsson, 2011), (Brundell-Freij et al., 2009). The papers have different perspectives, but taken together, they support all the processes and mechanisms described above.

- (Hårsman and Quigley, 2010) analyse referendum data and compare referendum results for each voting district with traffic effects and parliamentary election results. They show that both traffic effects and political views affect referendum results. Voting districts, which benefit more in terms of travel times or lose less from increased travel costs also show stronger support for the charges. Referendum results are also strongly correlated with political views: the support for charges is strongly correlated with the support for political parties that are in favour of the charges.
- (Eliasson and Jonsson, 2011) analyse attitude data from December 2007, i.e. in a situation where respondents are familiar with the congestion charges and their effects. They show that the effects of the charges, both on an individual level and on a system level, affect acceptability. Moreover, attitudes to general environmental problems strongly affect acceptability – strong environmental concerns increase support for the charges. They also show that there is "feedback loop" between attitudes to the charges and perceived system effects: positive attitudes to the charges increase the belief that the charges have had beneficial effects, and vice versa.
- (Brundell-Freij et al., 2009) study how belief in the effectiveness of the charges changed over time, and how this affected support for them. They conclude that belief in the effectiveness of the charges strongly affects opinions about them, but that the increasing belief in effects during the trial cannot entirely explain the increase in the support. They argue that the cognitive dissonance phenomenon most likely also contributed to the change in opinion. They also show that even those who did not believe in the effectiveness of the charges became less negative over time. This may be both because of cognitive dissonance and because they discovered that the anticipated negative effects of the charges were less than expected.

5.3. Achieving public acceptance: Moving beyond "winners/losers"

In the simplest textbook analysis of congestion charges with homogeneous users and aggregate supply and demand curves, all users will be worse off: either they are priced off the road to a second-best alternative, in which case they will obviously be worse off, or they stay on the road, in which case they will pay more than their value of the time gain. Theoretically, the revenue from the charges is sufficient to compensate the losers, so the standard recommendation in the acceptance literature is that congestion charges must be part of a "package", within which it is clear how the income is going to be spent to the advantage of the general public, if it is going to have any chance of being accepted (see for example (Goodwin, 1989), (Jones, 1991), (Small, 1992)). In the case of the Stockholm trial, however, virtually none of the income would be used for the direct benefit of motorists. While some of the income was used to improve public transport during the course of the trial,

not many were able to take advantage of this. The improvement of the public transport during the trial was hence presumably not an important reason for the increasing public support or the large effects on traffic reduction experienced during the trial. When the charges were reintroduced, however, most of the revenues were to be spent on a ring-road, which presumably increased acceptance among motorists (although there are unfortunately no studies of this). But it was evident that revenue use was less decisive for acceptance than expected.

Much of the economically oriented literature is concerned with the question of the "winners" and "losers" of congestion charges (see e.g. (Eliasson and Mattsson, 2006)), and the influence such equity effects may have on acceptability. The three papers above (especially (Hårsman and Quigley, 2010)) confirm that individual costs and benefits affect acceptability in the expected way. But all the papers also show that acceptance depends on many more factors than just the "winners/losers" dimension. It is also apparent that the simplest versions of transport-economic theory neglect some crucial aspects related to "winner/loser" analysis:

1. *The standard analysis of congestion charges underestimates the number of "winners" and the total benefit of congestion charging.* This is because the standard "textbook" analysis neglects three things: dynamics, network effects and user heterogeneity. In a dynamic model, where users can adjust their departure time, users will not necessarily lose from a congestion pricing reform. In the simplest case with a single bottleneck, the optimal toll will shift travellers to arrive at a rate that never exceeds the bottleneck capacity. Hence, there will be no queue, the toll and rescheduling costs will not exceed time spent in queue before the toll, and no user will be worse off (see (Vickrey, 1969), (Arnott et al., 1993), (Arnott et al., 1994)). *Network effects* will mean that some drivers will benefit from time savings without paying the charge. If a charge reduces traffic in a congested bottleneck, all upstream traffic will benefit – not only drivers actually going through the bottleneck and hence paying the charge. *Heterogeneity* among travellers will mean that congestion charges will tend to "sort" trips such that high-valued trips will stay on the road (and enjoy time benefits), while low-valued ones will be priced off. From an acceptance perspective, the important point is that individuals can belong to different valuation "groups" on different days or different journeys.
2. *Perceived "system" effects also affect acceptability.* In other words, it is not just perceived individual costs and benefits that determine acceptability. Hence, the "branding" of the charges matters – how they are marketed, explained and perceived. A condition for this to be possible is that the system design is well aligned with the stated purpose of the charges. In Stockholm, the support for the charges was closely correlated to general environmental attitudes. Hence, the labelling of the charges as "environmental charges" and emphasising their positive effects on air quality probably increased acceptability. While most of the social benefits of congestion charges will in general be time savings, decreasing car traffic will also generate environmental benefits, such as improved local air quality, perceived urban environment and (to some extent) reduced carbon emissions. Many people are ready to suffer inconvenience or increased costs for the environment, while a great deal fewer are prepared to suffer to achieve a more economically efficient use of scarce road capacity. If congestion charges are marketed only in the latter way, then it seems unlikely that they will gain sufficient public support.
3. *Identifying "winners/losers" rapidly becomes impossible.* Travel patterns are not static. Even when no external conditions change,

travel patterns are much less repetitive and stable than many people think. Many of the affected drivers will be “occasional car drivers”, who drive on the charged road perhaps a couple of times each month. Less than a third of car drivers across the Stockholm cordon are “habitual” car drivers that pass the cordon each day. Moreover, identifying “winners” and “losers” is in fact only possible in the short-term. Over a longer time period – a few years – the entire choice context (workplace and residence location, scheduling restrictions, leisure activities) will have changed. The charges will then have changed from being an “external shock” to being a factor considered when making all these choices. In that perspective, “winners/losers” will be impossible to identify. This is illustrated by the finding that when motorists in Stockholm were asked if the congestion charging had made them change their travelling habits, there were too few answering “yes” to correspond with the actual reduction in measured traffic volumes. Car drivers had apparently changed behaviour without even noticing it.

4. *Preferences and attitudes are not static.* As discussed above, the introduction of congestion charges may in itself change attitudes, through processes such as cognitive dissonance or less resistance against pricing as a policy measure. The paper by Quigley and Hårsman also shows that attitudes to charges are correlated to the standpoints of the political parties – and these may change over time. In the Stockholm case, one may presume that the fact that all political parties now support the charges has increased acceptance further.

5.4. The concept of “fair” charges

Another problem with the “winners/losers” perspective concerns the way this translates to the question of “fairness”. Often, if a system affects high-income groups more than low-income groups, it is claimed to be a “fair” system. Hence, “fairness” considerations – which are known to affect acceptability – are interpreted as a question of identifying “winners and losers”. In Stockholm, the equity effects were generally speaking progressive: high-income groups paid more than low-income groups, men paid more than women, employed more than unemployed etc. (Details can be found in (Eliasson and Mattsson, 2006), Eliasson and Mattsson, 2006; (Eliasson and Levander, 2006), (Franklin et al., 2010).)

But once the charges are in place, and the short-term winner/loser perspective fades, another perspective becomes more important: what price is actually “fair” to charge for a car trip? From this perspective, it is “fair” that one pays more to drive on a congested road or to cause emissions in densely populated areas – irrespective of income or place of residence, or what a hypothetical travel pattern would have been without the charges. This means that a system needs to be perceived as “fair” in this sense: it needs to be consistent with its stated objective. In Stockholm, one of the most common objections to the system nowadays is that traffic within the cordon is not charged. Although there are two good answers to this (the congestion is mainly located on the arterials along the cordon; most of the traffic inside the cordon crosses the cordon at some point on the trip), this shows how the debate has moved from “who wins/loses” to “what’s fair relative to the objectives”.

5.5. Political acceptability

Political acceptability is different from public acceptability. Obviously, political acceptability is influenced by the level of public acceptability – but public acceptability is neither a necessary nor a sufficient condition for political acceptability. Crucial for the analysis

and understanding of political acceptability are power issues: the power over the design of the charging scheme, the power over the revenues, and how the charges and their revenue stream will affect decisions and funding of transport investments in general. The fact that congestion charges are now politically accepted in Sweden is not only, or perhaps not even primarily, due to the higher public support. It is also because the charges have been integrated in the general transport investment planning process, and this has – at least partly – solved the power and negotiation issues above.

To understand the political and institutional drivers behind this development, one must start with the legal context. Swedish congestion charges are not “charges” but national “taxes” from a legal point of view. Existing infrastructure cannot be “charged”, only “taxed”, according to the constitution’s definition of a charge, and Swedish municipalities⁶ cannot levy taxes on other than their own citizens. Hence, although it was the city of Stockholm that was responsible for designing the charging system and carrying out the congestion charging trial, the responsibility for actually levying and administering the charges had to be assumed by the national government.⁷ More important, this meant that it is the national government that has the formal power over both scheme design and revenues. Although the Government promised to refund the revenues to the Stockholm region, disagreements quickly emerged regarding how revenues should be calculated, how revenues should be used and which vehicles should be exempt. Further disagreements, such as whether and how charge levels should change along with inflation and economic growth, can be expected. Many politicians have stated that their main argument against introducing the congestion charge was the uncertainty about the political power over scheme design and revenues.

Adding to these uncertainties was the uncertainty about how the existence of the new revenue stream would affect the complicated negotiation between national and regional levels about national infrastructure grants. Most of the major transport investments in Sweden are paid for by the national government, whereas municipalities and regions are responsible for local streets and transit operation. As expected, there is often disagreement on where the border between different responsibilities should lie. The politicians in Stockholm, regardless of political colour, had long argued that they were not receiving their fair share of national infrastructure grants. Whether this claim was founded or not, it meant that the arrival of a new revenue stream in the form of congestion charges was not necessarily welcomed. Several politicians feared this would mean that Stockholm would have to pay an even larger share of transport investments with their own money. The government, they argued, would point to the revenues from the congestion charges and claim that Stockholm obviously needed even fewer national infrastructure grants than before.

The solution to this dilemma was the so-called “Cederschiöld agreement”, named after the chief negotiator appointed by the Government. In this agreement, the charge revenues were funding parts of a major transport investment package, where the national government also made a major funding commitment – much larger than had been the case for a long time. The charge revenues were earmarked for the road investments in the agreement, while the substantial rail investments were claimed to be paid for with money from other sources. An agreement was settled in late 2007, eventually only between centre/right parties

⁶ A “municipality” (“kommun” in Swedish) is the smallest geographical administrative unit in Sweden, roughly corresponding to a city. Most of the spatial planning responsibility, including infrastructure planning, lies at the municipal level.

⁷ This task was given to the National Road Administration, and later moved to the National Transport Agency.

on the national and regional levels. With this, support for the charges had been secured from regional politicians of all parties. Ironically, the Cederschiöld agreement contained several investments that the Left and Green parties – the original main proponents of congestion charges – had been opposing for many years. The result was a situation where all parties agreed to keep the congestion charges, but with different main motives, ranging from car traffic reduction (Lefts and Greens) to investment funding (Centre/Right parties), and with different opinions on how the revenues should be used.

5.6. The impact on the Swedish transport investment planning process

The Cederschiöld agreement was a forerunner for a major change in the Swedish investment planning process. As part of the preparation for the national investment plan in 2010–2021, the Government declared that investments receiving regional co-funding would be given higher priority. There were two reasons for this: to increase the total amount of available funds, and to give regions better incentives to prioritise among their suggested investments. Regional co-funding could come from any source, but several regions jumped at the opportunity to introduce congestion charges as a means to obtain such funding. Congestion charges are in fact now being introduced in several other cities, with Gothenburg (Sweden’s second largest city) leading the way. In these cases, the main motivation for introducing charges is to finance transport investments, in contrast to Stockholm. In several cases, “congestion” charges are a misnomer, since the cities have no traffic congestion at all (with Gothenburg a possible exception). Gothenburg is a particularly illuminating example of the loose connection between public and political acceptance. In Gothenburg, a broad political consensus was formed, where congestion charges would pay for roughly half of a large investment package, with the other half coming from the Government. This is a surprising and stark contrast to the extreme controversy when Stockholm introduced charges, and even more surprising considering that acceptability levels in Gothenburg have always been very low, typically hovering around 20%. Despite this, Gothenburg politicians from all parties are now embracing congestion charges.

Giving regions the incentive and opportunity to introduce road user charges to obtain transport investments, where regional funds are leveraged by national funds, may fundamentally change the transport investment planning process. There are several advantages: regions are given an incentive to prioritise between transport investments and other responsibilities, as they are forced to “put their money where their mouth is”. When there is congestion, regions are more likely to introduce congestion charges, which is obviously a potent and efficient policy measure. On the other hand, there are several disadvantages: since regional funding is leveraged, regions will be tempted to over-invest in transport infrastructure relative to other types of (non-leveraged) spending. Charging traffic above the marginal social cost – which financing charges will probably do – will typically cause deadweight losses (although this depends on the net benefit of the investment and the deadweight loss of alternative funding sources). Whether future Governments will be able to control what they have let loose remains to be seen.

6. Conclusions

When congestion charges were introduced in Stockholm January 2006, the effects were substantial and immediate. Since then, however, there has been an ongoing discussion about whether the effects are likely to wear off over time, when drivers

become used to paying the charge. In this paper, we have shown that the effects of the charges have instead increased slightly over time, once factors such as employment growth, inflation and changed tax regulations are controlled for. In other words, the long-term cost elasticity turns out to be somewhat higher than the short-term cost elasticity. This is in line with what is usually found when comparing long and short-term elasticities, since more adaptation mechanisms are available in the longer term.

Two other fears were that the charges would lead to increased congestion problems on other links, especially the bypasses, or that the freed-up road space within the cordon would quickly be filled up with other traffic. After four years, there is no evidence of these effects. Similarly, the improvements in travel times and travel time variability remain (although in this case, there is no data after 2008).

In an effort to stimulate demand for alternative fuel vehicles, such vehicles were exempt from the charge up until the end of 2008. This policy has had a considerable effect on the sale of alternative fuel vehicles.

Perhaps the most surprising effect of the Stockholm charges was the change in public and political acceptance, from vehemently negative to considerable support. We argue that it is necessary to consider public and political acceptance separately: while political acceptability is influenced by the level of public acceptability, public acceptability is neither a necessary nor a sufficient condition for political acceptability.

There seem to be several reasons contributing to the public support for the congestion charges in Stockholm. The most striking effects were of course the reductions in congestion and emissions, and this has certainly increased support for the charges. But conversely, the discovery that the charges were not as bad as feared also played a role: adaptation and increased travel costs proved to be less of a burden than many seem to have anticipated, especially seen over a longer period of time.

So, what does it imply for cities aiming at introducing congestion charges, that public acceptance tends to be low before the introduction of the charges? Experiences from Stockholm suggests that this may be a moderate problem because introduction of congestion charges is more dependent on political acceptability, which does not necessarily coincide with public acceptability, at least in the short-term. Moreover, while the extended public transport during congestion charging trial seems not to have had any major effect on the public opinion in Stockholm, access to efficient public transport and “slow modes”, which in general are good in Stockholm, are probably an important factor for a public opinion in favour of congestion charges.

The essential factor for achieving political support in Sweden for congestion charges is the integration of the charges into the national investment planning process, thereby giving local and regional politicians substantial influence over the use of the revenues. Political support would most likely increase further if regional politicians were given more power over system design (charge levels, exemptions etc.). Moreover, the charge revenues are leveraged with additional national investment funding. The practice of leveraging regional funds with national ones can prove troublesome, since it creates incentives to over-invest in transport investments to the detriment of other public sectors. However, this is still an improvement compared to past practice, where regions seldom had to co-fund transport investments at all.

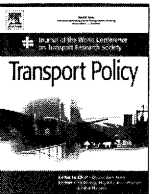
In summary, the Stockholm case has several policy implications that may be useful for other cities considering introducing congestion charges. It is crucial for the legitimacy of introducing congestion charging in other cities that the effects persist in the long-term, which indeed is the case in Stockholm. Moreover, deeper knowledge of long-term effects is crucial for designing new charging systems and developing the existing ones. The

finding that adverse effects on uncharged roads are small, for instance, is important for the justification of congestion charging, as well as the increasingly positive public opinion in favour of charges once they have been introduced. The Stockholm case also suggests that the crucial political support for congestion charging largely depends on if regional politicians have influence over the use of the revenues and the design of the system.

Even if the effect of the charges persists, population growth would require the charges to increase in order to restrain a continuous increase in traffic flows across the cordon. Moreover, the bypass E4/E20 is currently heavily congested, building up queues far out in the traffic network in all directions around the inner city due to blocking back of upstream links, but has not been charged for political reasons. An obvious future improvement of the Stockholm congestion charging system would be to have charges levied also on the bypass E4/E20, which would increase the welfare benefit considerably. This kind of extensions of the system are facilitated by the positive long-term effects of the charges found in the present paper.

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Estimation of indirect cost and evaluation of protective measures for infrastructure vulnerability: A case study on the transalpine transport corridor

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ABSTRACT

Infrastructure vulnerability is a topic of rising interest in the scientific literature for both the general increase of unexpected events and the strategic importance of certain links. Protective investments are extremely costly and risks are distributed in space and time, which poses important decision problems to the public sector decision makers.

In an economic perspective, the evaluation of infrastructure vulnerability is oriented on the estimation of direct and indirect costs of hazards. Although the estimation of direct costs is straightforward, the evaluation of indirect cost involves factors non-directly observable making the approximation a difficult issue. This paper provides an estimate of the indirect costs caused by a two weeks closure of the north–south Gotthard road corridor, one of the most important infrastructure links in Europe, and implements a cost–benefit analysis tool that allows the evaluation of measures ensuring a full protection along the corridor. The identification of the indirect cost relies on the generalized cost estimation, which parameters come from two stated preference experiments, the first based on actual condition whereas the second assumes a road closure. The procedure outlined in this paper proposes a methodology aimed to identify and quantify the economic vulnerability associated with a road transport infrastructure and, to evaluate the economic and social efficiency of a vulnerability reduction by the consideration of protective measures.

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1. Introduction

Interruptions in infrastructure networks generate considerable economic and social damages at the regional and national level according to the overall dependency of the network on certain links and the risk associated with this interruption. In the context of increasingly vulnerable networks due to climate change, the attention on transport network reliability has grown substantially in the recent years in the international science community (Bell and Iida, 2003; Nicholson and Dante, 2004). Berdica (2002) introduces the road transport vulnerability as a complement of reliability, that is, the non-operability of a system due to incidents caused by either natural or man-made hazards.

Vulnerability assessment of a given transport infrastructure is mostly oriented on an engineering approach and regards the identification of the weakest points in a transportation network. Numerous methods have been proposed based on, for example,

connectivity reliability (Bell and Iida, 1997), capacity reliability (Chen et al., 2002) or accessibility index (Taylor et al., 2006).

In an economic perspective, the evaluation of infrastructure vulnerability is oriented on the estimation of direct and indirect costs of hazards. The former are associated with damages on the infrastructure caused by an unexpected event whereas the latter regard the consequences that the damaged infrastructure provokes on the society that depends on it. Although the estimation of direct costs is straightforward, the evaluation of indirect cost involves factors non-directly observable making the approximation a difficult issue. D'Este and Taylor (2003) proposed to calculate the loss of amenity of a link interruption as the change in generalized cost weighted by travel demand. Different algorithms have been proposed, as, for example, the short path algorithm. However, Taylor and D'Este, 2004 recognized the limit in using algorithms as estimates of change in the utility of travel.

The estimation of the cost associated with an interruption of an infrastructure link is necessary in order to evaluate the desirability of any protective measure that allows a reduction of the vulnerability of the network to which it belongs. In this sense, a given vulnerability of a network represents a level of (expected) direct and indirect cost of a given hazard risk. Reducing vulnerability via

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