Transportation Research Part A 43 (2009) 240–250

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

The Stockholm congestion – charging trial 2006: Overview of effects ☆

Jonas Eliasson [a], Lars Hultkrantz [b,*], Lena Nerhagen [c], Lena Smidfelt Rosqvist [d]

[a] Royal Institute of Technology, Sweden
[b] Örebro University, Sweden
[c] VTI, Swedish National Road and Transport Research Institute, Sweden
[d] Trivector Traffic AB and TransportMistra, Sweden

ARTICLE INFO

Keywords:
Road toll
Urban road pricing

ABSTRACT

The Stockholm congestion charging trial in 2006 demonstrated the effects of a full-scale time-differentiated urban road toll scheme. Improvements in travel times were large enough to be perceived by the general public. This was pivotal to the radical change of public attitudes that occurred during the trial and that resulted in a positive outcome of a subsequent referendum on a proposal for making the system permanent. This paper summarises the effects of the trial and analyses to what extent targets were met. Effects on congestion reduction were larger than anticipated, which also resulted in favourable economic and environmental effects. The trial showed that a single-cordon toll could affect traffic within a large area, i.e., not just close to the zone limits.

1. Introduction

The Stockholm congestion charging trial was performed from January 3–July 31, 2006. It included a road toll scheme, formally a tax decided by the national parliament, supplemented by extension of public transport services from August 31, 2005–December 31, 2006. The trial demonstrated to citizens how a congestion-charge[1] scheme works before they were to vote on whether to establish a permanent scheme in a referendum[2] held September 17, 2006.

The stated purpose of the road toll trial (or demonstration) was to "test whether the efficiency of the traffic system could be enhanced by congestion charges" (City of Stockholm, 2006a). The toll was expected to "reduce congestion, increase accessibility and improve the environment" (both the perceived living environment and the measurable emissions from car traffic) (City of Stockholm, 2003). The toll rate was set so as to reach the target of reducing car traffic across the cordon with 10–15%. This target was (loosely) based on previous studies on the design of road toll schemes in Stockholm.

The trial turned out to be a milestone in the development of urban road pricing. First, to the surprise of all but a few hard-headed road toll enthusiasts, it finally tipped the balance of a 40-year political consideration of road tolls in Stockholm by invoking more or less a land-slide change of the opinion of the general public in favour of tolls. This finally resulted in the implementation of a permanent scheme from August 2007 in response by the newly elected national government to

☆ We are grateful to contributions from the other members of the evaluation team: Staffan Algers, Karin Brundell Freij, Cecilia Henriksson, Muriel Beser Hugosson, and Christer Ljungberg, and to comments from three referees.

* Corresponding author. Tel.: +46 19301416; fax: +46 19332546.
E-mail address: lars.hultkrantz@oru.se (L. Hultkrantz).

[1] Legally, the congestion charge is a tax, according to Swedish law, and the official Swedish term is hence "congestion tax". We have chosen to use the international standard term "congestion charge".

[2] This was a legally non-binding advisory referendum held in Stockholm the same day as new national and local parliaments were elected. Some, but not all, of the municipalities surrounding the City of Stockholm held similar referenda, although these municipalities had no formal saying in the decision on whether to implement the road toll.

0965-8564/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tra.2008.09.007

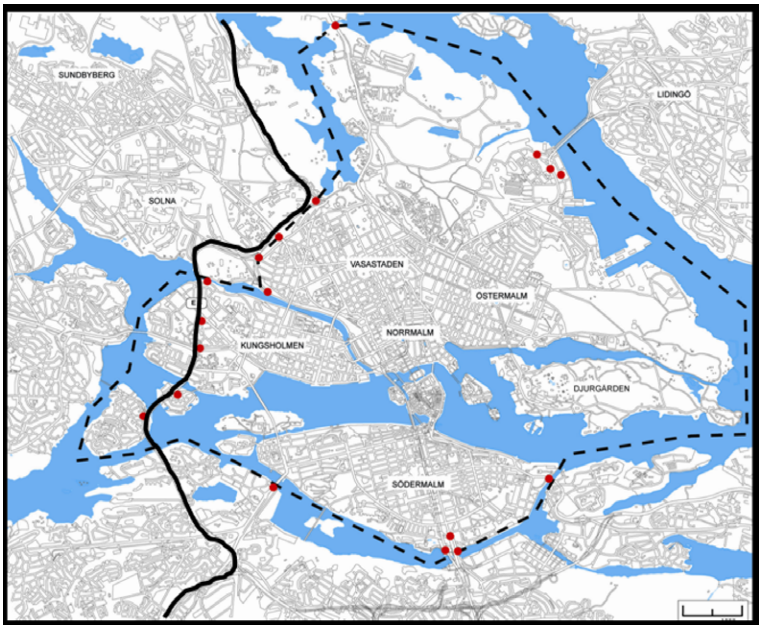

Fig. 1. The charged area. The dashed line is the charging cordon, the dots are charging points and the solid line is the non-charged Essinge bypass.

the outcome of the referendum vote. Second, it was the third full-scale demonstration of an urban congestion charge, after Singapore and London, and the second to be based on a time-differentiated scheme, after Singapore.

Being a political rather than scientific project, the trial did not have an experimental or quasi-experimental design. Evaluations of the effects of the trial therefore have to rely on before-during-after comparisons. As further described in Gudmundsson et al. (2009) traffic in the City of Stockholm and behaviour of road users in the whole county were monitored before, during, and after the trial by a wide range of automatic and manually operated systems, surveys to residents and focus groups, etc. The authors of this article were members of an expert committee appointed by the City of Stockholm for analysing this data and to assess the overall effect, based on some 20 studies of various specific issues that were made in parallel. Two of us were involved also in these special studies, and one even in the design of the charge scheme. A report from the expert committee was published monthly during the trial and immediately after the trial was completed. Later, we have gained further insight from analyses of data from continued monitoring after the completion of the trial. Here, we summarise our main findings.

2. Design of the congestion-charge scheme

During the trial, charges were imposed on vehicles passing a cordon around the inner City of Stockholm as depicted in the map of Fig. 1. The area of the toll zone is around 30 km^2.[3] The zone has a little less than 300 000 inhabitants, of which approximately 60,000 commute to workplaces outside of the zone. The zone has close to 23,000 workplaces, employing approximately 318,000 persons, of which more than two-thirds are commuting from outside the zone.

Charges were time-differentiated over the day and over the week as shown in Table 1. The fee for passing a control point was SEK 10, 15, or 20, respectively (corresponding to Euro 1.1, 1.6, and 2.2, respectively) depending on the time of day (while London initially charged £5 per day, between 7:00 and 18:30, later raised to £8 per day). No fees were levied in evenings, nights, Saturdays and Sundays, public holidays or a day before such a holiday.[4] Various exemptions (for e.g. taxis, buses, eco-fuel cars and for bypass traffic from and to the island of Lidingö) made nearly 30% of all car passages free-of-charge. Equal fees were charged in both directions. The total daily payment of a vehicle was limited to SEK 60.

One route (the Essinge bypass, shown as a solid line in Fig. 1) was open free-of-charge for north-south or vice verse bypass through the toll zone. This exemption was introduced in response to political resistance to road tolls in Stockholm from surrounding municipalities.

As a supplement to the congestion-charge scheme, public transport services were extended with 16 new bus lines, beginning operations 4 months before the start of the tolling. This provided effective and fast alternatives for travelling at peak hours from the municipalities surrounding Stockholm into the inner city. Also, where possible, existing bus, underground

[3] As a comparison, the congestion charge scheme of London introduced in 2003 encompassed a 21 km^2 zone, this was almost doubled by the western extension in 2007.

[4] Traffic is usually less intense on such a day).

Table 1
Charges in different time intervals (levied on weekdays only)

6:30–7:00	10 kr
7:00–7:30	15 kr
7:30–8:30	20 kr
8:30–9:00	15 kr
9:00–15:30	10 kr
15:30–16:00	15 kr
16:00–17:30	20 kr
17:30–18:00	15 kr
18:00–18:30	10 kr

and commuter train lines were reinforced with higher capacity and additional departures. In total, the entire range of public transport services was extended by 7%. Also, new park-and-ride facilities were built in the region, increasing the park-and-ride capacity with 29%.[5] Existing park-and-ride facilities were made more attractive. As the extended public transport services started before the charging scheme was activated, their stand-alone effects can, to some degree, be separated out (see Kottenhoff and Brundell Freij, 2009).

3. Traffic effects

3.1. Effects on traffic volumes

Based on traffic-model simulations made before the trial a 10–15% reduction of the number of vehicles crossing the cordon was expected during charging hours. In fact, the traffic forecasts predicted a larger and, as it turned out, more correct predicted magnitude of 20–25% (Eliasson et al., 2003a,b, 2004) – but such a large decrease seemed unreasonable at the time, even to the modellers themselves. No forecasts were made of the effects on accessibility, as the static network equilibrium models available for forecasting were considered as not being reliable for such purposes.

Indeed, traffic flow across the cordon decreased almost exactly as projected in the mentioned studies. The traffic reduction compared to 12 months before[6] stabilised after the first month at around 22% (see Fig. 2). After the charges had been abolished, traffic almost returned to previous volumes – but it seems as though a small effect of the charges remained, as traffic across the cordon during the autumn of 2006 was a few percent lower than during the autumn of 2005. However, this effect was concentrated to two bridges on the cordon line where major roadwork was carried out during the autumn, so it is uncertain what conclusions can be drawn from this.

In relative terms, the decrease was largest in the afternoon peak period (−23% between 16:00 and 18:00), and somewhat lower in the morning peak period (−18% between 7:00 and 9:00). This indicates that a larger share of discretionary trips is made during the afternoon peak than in the morning and/or that departure times from work are less fixed than arrival times to work. Traffic declined in evenings as well. Hence, the reduction of outbound traffic during evening because of fewer incoming vehicles in the morning outnumbered the increase of evening traffic because of within-mode substitution from travel during day-time to free-of-charge evening. Despite the lower charge during mid-day (9:00–15:30), traffic decreased almost as much during this period (−22%). The seemingly high cost sensitivity during this time period is partially explained by the fact that many of the trips crossing the cordon during mid-day pay the higher charge when going in the other direction.

As can be seen in Fig. 3, effects on traffic were seen further out from the toll zone than initially was expected. Traffic volumes declined at locations far from the toll cordon. Consequently, unwanted side effects that were anticipated outside the cordon, such as an increase of traffic on link roads at the city's outskirts, were not found.

Traffic flows in major inner city streets declined to a lesser extent than the flows over the cordon (see Fig. 3), since car traffic entirely inside the cordon was not charged. Also, the tolls probably induced an increase of distance per vehicle within the zone, both as a result of reduced congestion and as a substitute for transport by displaced vehicles. Still, the total traffic work in terms of kilometres driven in the inner city decreased by 15%.

In comparison, this effect is approximately one-half of the effect (30% reduction) on private car traffic in the toll zone in London in 2003 (Transport for London, 2003)). As the London charge (£5) was approximately double the size of the average daily charge paid by toll payers in Stockholm (on average 28 SEK per vehicle and day), this is a rough indication of equal magnitude of toll elasticities. Another comparable measure is the implied cost elasticity. With a mean trip length of 17 km for private car trips across the cordon, this would imply a cost elasticity around −0.8 for private trips across the cordon (excluding route choice effects).

[5] The number of parking spaces, as averages during the months of April and May increased by 2886 from 2005 to 2006. The average number of parked vehicles increased by 1824, equal to 23% increase. The average occupancy level decreased from 78% to 74%.

[6] All comparisons of traffic flows and travel times are made with regards to measurements from 2005, and we hence assume that the differences between these 2 years can be attributed to the introduction of the congestion charge. This is supported by a time-series study analysing the effect on traffic levels of fuel price, employment and car ownership; see Eliasson (forthcoming) for details.

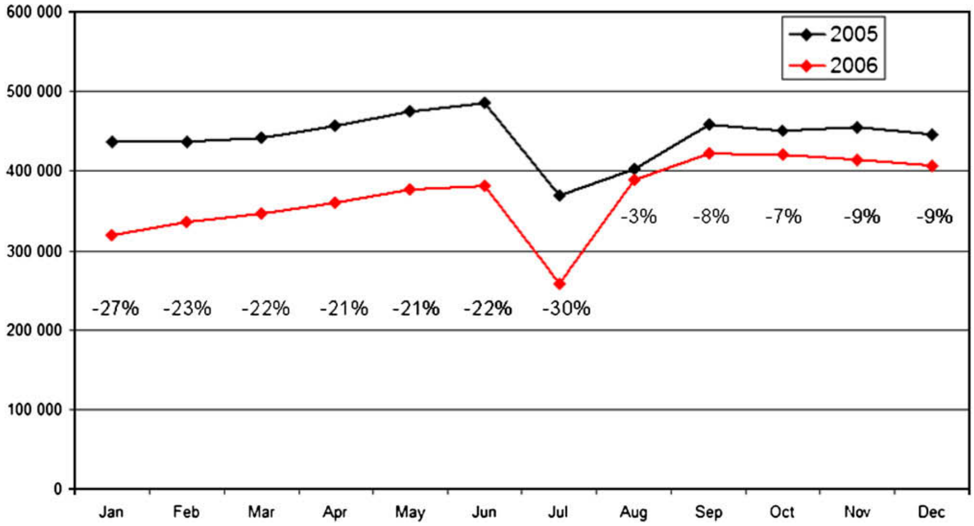

Fig. 2. The number of vehicles passing across the cordon during day-time (6.00–19.00 weekdays). The charges were in place weekdays 6.30–18.30, January 3–July 31, 2006. Data from September–December 2006 may be somewhat uncertain due to road works and problems with the measurement equipment.

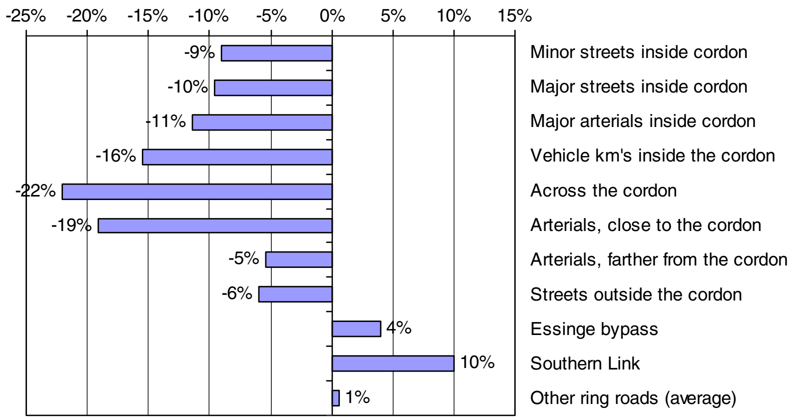

Fig. 3. Average changes of traffic volumes for different types of roads on weekdays 6.00–19.00, April 2006 compared to April 2005. The effect on the Southern Link is uncertain due to autonomous traffic growth; see text.

Since traffic on the toll-free Essinge bypass was close to capacity limits already before the trial, there were serious concerns before the trial of major breakdowns caused by traffic avoiding the cordon area. Also, increased congestion was expected on the Southern Link, which is a newly built ring-road tunnel outside the cordon connecting the southwest suburbs with the southeast and the Essinge bypass.

It turned out that traffic increased on the Essinge bypass by just a few percent (monthly averages increasing by 0–4%).[7] Average travel times on this route increased within normal variation. On the Southern Link (a bypass south of the cordon), however, both traffic volumes and travel times increased significantly compared to the spring of 2005. A large share of the increases on the Essinge bypass and on the Southern Link seems to have been due to autonomous traffic increase: traffic on theses links have been steadily increasing over the years, and when charges were abolished, traffic on these links did not decrease but instead continued to increase in virtually the same pace.

3.2. Effects on travel times

The primary data source for travel times was the travel time measurement camera system, operating continuously since April 2005. For the evaluation, travel times for six consecutive weeks in April–May 2005 and 2006 were used. As a complement, floating car measurements were used.

[7] This increase remained after the end of the trial. Therefore, at least to some extent, it may have had other causes than the congestion charge.

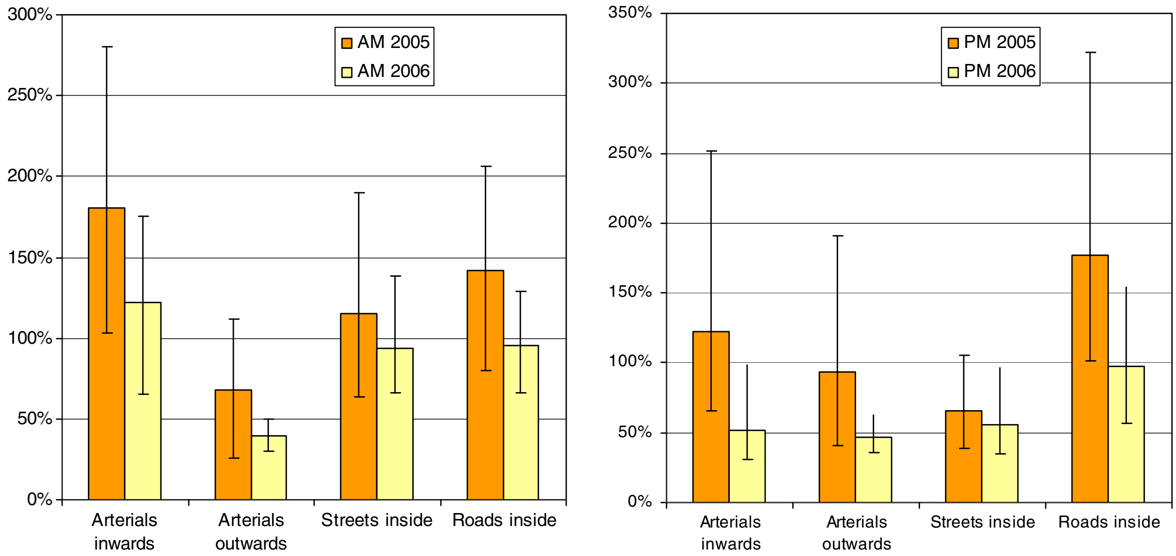

Fig. 4. Relative increase of travel times for various categories of links. 0% corresponds to free-flow travel time. The coloured bars show average travel times while the "error bars" indicate the worst decile and the best decile of the travel times distribution. Measurements were taken from all weekdays for 6 weeks in April–May. "AM peak" refers to 7.30–9.00, "PM peak" refers to 16.00–18.00.

As a consequence of the decline of vehicle traffic, travel times fell. Travel times for vehicle traffic declined substantially inside and close to the inner city (see Fig. 4). Particularly large declines were seen on arterials, on which delay times[8] fell by one-third during the morning peak period and by one-half during the afternoon/evening peak period. This is of the same order of magnitude as in London 2003, for which congestion, measured in terms of delay per kilometre, is reported to have decreased by 32%.

This considerably improved reliability of travel times, i.e., travellers could be more certain about the duration of a car trip. Duration of the highest decile of the travel time distribution fell to a third or less compared to the pre-trial state for some categories of roads (such as arterials during PM peak).

Travel times on the Essinge bypass did not increase significantly, while on the Southern Link, travel times were considerably higher during spring 2006 than in the spring the year.

Some studies indicate that the decline in traffic volumes and improved accessibility was visible to road users as well as the general public. For example, according to Transek (2006a) the perceived quality of working environment of commercial drivers (lorry and bus drivers) improved, and according to Transek (2006b) the number of citizens viewing congestion as a severe problem decreased significantly.

Regarding the increase of traffic and travel times on the Southern Link, it is unclear how much of this that was due to an autonomous traffic increase. The Link opened as late as in October 2004, and traffic increased steadily during the first year, until a boat hit a vital bridge on the Essinge bypass, temporarily reducing traffic also on the Southern Link. The bridge was then restored to full capacity at the same time as the charges were introduced, and the traffic flows on both the Essinge bypass and the Southern Link increased overnight. Based on the short time series available, our tentative estimate is that the charges contributed to an increase of traffic on the Southern Link by around 5–10%. However, traffic on the Southern Link did not decrease later when the charges were abolished, suggesting that the impact from the charges was even smaller.

4. Effects on travel patterns

Two travel surveys were carried out (Trivector, 2006a), one before the trial period (in the autumn of 2004) and another during the trial (spring, 2006). They were designed as panel surveys covering around 40,000 completed 1-day travel diaries. Initially, the trial was planned to start in August 2005, so the second travel survey was planned to be carried out during that autumn, 1 year after the first. As the start of the trial was postponed (due to legal complaints), the second travel survey during the trial had to be made at a different season and one and a half-year after the first. Confounding from seasonal changes and other factors changing over time made the analysis of the survey data difficult.

Nevertheless, the results from surveys indicate that around half of the evicted car trips (45,000 out of 92,000) consisted of travel to and from work and school. Virtually all these travellers (43,000) ended up using public transport (corresponding to

[8] Delay times were measured as relative increase of travel times above free-flow travel times. Zero percent delay time hence means free-flow travel times, while 100% delay time means a doubling of the travel time relative to free-flow travel time.

a 6% increase of public transport trips). Surprisingly, there was no sign of neither more car-pooling nor more telecommuting. The other half of the evicted car trips was mainly discretionary trips. Virtually none of these ended up in public transit. In fact, it turned out to be difficult to trace how they were substituted. Probably, some of these travellers changed destination (not crossing the cordon), other trips were completely cancelled or combined with trips for other purposes.

Further, the travel surveys confirm that some compensating increase of car travel demand was induced by the reduction of inner city congestion. Commuters that were travelling inside the cordon only increased their travelling during peak periods, and more of them used car.

5. Environmental effects

5.1. Emissions from traffic

The Stockholm trial reduced emissions of carbon-dioxide and health-related emissions from car traffic such as particles. Generally speaking, the amount of emissions from traffic depends on vehicle kilometres and emission factors. The emission factors in their turn depend on the types of vehicles used and on driving conditions (driving patterns) in the street network. For example, driving with large variations in speed produces more emissions than driving at an even speed (Ericsson, 2001). Both the composition of vehicles and driving patterns were affected by the trial. For example, the trial involved an extension of public transit services by buses that use diesel fuel (though a few buses used biogas), which therefore had to be taken into account in the calculation of the effects of the trial on emissions.

Two different impact models were used to assess these effects (Carlsson et al., 2006; SLB Analys, 2006). To assess the changes in the concentration levels air quality dispersion models have been used since measurement data in the short term to a large extent is influenced by weather conditions. The basis for the air pollution modelling was the traffic analyses carried out in connection with the trial together with the Stockholm and Uppsala county Air Quality Associations' emissions databases (SLB Analys, 2006). Hence, the estimates are based on detailed data with high spatial resolution.

Both studies arrived at similar results. However, as none of them considered the possible effects of the trial on driving patterns, the reductions of emissions were probably underestimated (Smidfelt Rosqvist, 2003).

The decrease of carbon-dioxide emissions from inner city traffic was estimated to 14%, which is slightly less than the overall reduction of traffic within the toll cordon (16%). This corresponds to a reduction of these emissions from traffic in the whole metropolitan area (the county of Stockholm) by 2–3%. The estimated reductions of air-borne pollutants inside the cordon varied from 10% to 14%. For nitrogen oxides (NOx) the reduction was smaller (8.5%). Further inquiries revealed that the reason was that the extended bus traffic used older buses with higher emission factors. Overall, the results reveal that air quality was improved in many streets in the inner city.

The use of air pollution modelling allowed for a detailed assessment of the changes in population exposure due to the change in traffic. Since the main effects were seen inside the cordon where the day-time population density is high, this also results in important changes of average population exposure. The estimated reductions of NOx and exhaust particles emissions are refer to the change in concentration at rooftop level in the inner city (so-called urban background). This provides an indication of the average load of the population in this part of Stockholm.

International research ascribes reduced mortality due to for example fewer cases of cardiovascular diseases and lung cancer as the most important health benefit. Forsberg et al. (2006) estimate, based on an exposure-response function from Oslo (Nafstad et al., 2004), that there will be 20–25 fewer premature deaths per year in Stockholm's inner city and a total of 25–30 less premature deaths annually in the Stockholm metropolitan area (see also SLB Analys, 2006).[9] These are approximately three times larger effects than what would be found if a more general policy measure, such as a fuel tax increase, was used to obtain a decrease of emissions of an equal magnitude, since these reductions were concentrated to the most densely populated areas.

5.2. Perceived urban environment

The survey studies made especially for elucidating urban environment changes suggest that the residents of Stockholm perceived improvements of those urban environmental factors for which changes can be measured, i.e., those connected to traffic reductions. Citizens expressed that they had experienced improvement of air quality, vehicle accessibility and from less intense traffic. Similar findings were made in interviews with inner city bikers and children living in the inner city. Bikers appreciated that there were fewer cars and less congestion. Inner city children's perceptions of the city environment were found to be clearly improved. On the other hand, these surveys also indicate that accessibility by foot, bike, and public transport was perceived to have deteriorated. This is a surprising finding. However, the interviews before the trial were made in a late and warm spring, while the interviews during the trial were made earlier during spring when the weather was still cold (with snow still partially covering the ground), which possibly can explain this.

[9] The standard cost-benefit model used for infrastructure planning in Sweden has a dose-response relationship based on older studies. This indicates that the reduction in traffic due to the trial saved about five life years on an annual basis. This is the number used in the cost-benefit analysis by Eliasson (forthcoming).

6. Road safety

Effects of a traffic measure on road safety are generally difficult to evaluate and the short period of the Stockholm trial made this even harder. The evaluation of the trial's effects on road safety (Trivector, 2006b) is therefore based on computations using previously estimated relationships between road safety and changes in traffic volumes, traffic flows and speed levels (Elvik et al., 1997).

The total number of road traffic accidents in the city of Stockholm according to police reports increased by 5% from 2005 to 2006 (the national total increased by a little less than 0.6%) while the number of fatalities decreased from 9 to 7 (the national total increased from 440 to 445). In attributing effects to the trial, Trivector (2006b) calculate that the decrease of traffic volumes reduced the number of personal injury accidents within the tax cordon during the trial by 9–18%. However, the higher average speed can be expected to have raised accident numbers (Nilsson, 2000) and increased the severity of accidents. Taking into account that a large share of the traffic accidents within the charging zone occur during the hours when the charge was imposed, Trivector (2006b) conclude that there still was a net reduction of the number of traffic-related injuries inside the cordon by 5–10% (corresponding to 40–70 injuries per year).

7. Public transport

The number of passengers by public transit was 6% larger in spring 2006 than 12 months earlier (Stockholm Transport, 2006a). Based on back-of-the-envelope elasticity calculations, we estimate that 1.5% can be attributed to changes of petrol prices and business-cycle effects, leaving 4.5% to be the result of the road toll.

We have been unable to confirm that the substantial efforts during autumn 2005, i.e., before the start of the trial, to improve public transport (park-and-ride sites, expanded bus and light rapid-transit train services) had an effect on the total number of public transport trips. That is not say there is no such effect, just that, if it exists, it is too small to have been recorded in SL's passenger statistics or in the travel habits survey conducted in autumn 2005 (Trivector, 2006a). Indeed, we find it unlikely that such a large enhancement of public transport services would not have had *any* effects on the total number of journeys by public transit. SL's onboard surveys on the new buses indicate that they indeed enticed some motorists to switch to public transport but their numbers are too small to make a noticeable impact on aggregate levels. Totally, travel with SL was about 2% higher in autumn 2005 than in autumn 2004 but that increase is believed to be due to higher petrol prices. Kottenhoff, Brundell Freij (2009) also argue that the expansion may have had a small stand-alone effect on modal split.

Another issue is what effects the congestion tax would have had in the absence of the extension of public transport. Conceivably, the effect of the congestion charges were boosted as modal switch from car to public transport was made easier. If that is the case, part of the effects of the congestion tax should instead be registered as an effect of interaction with expanded public transport. Similar conclusions are made by Kottenhoff, Brundell Freij (2009).

Still, we believe that this interaction effect is small. We base this conclusion on the finding that onboard surveys show that the number of passengers on the new bus lines in spring 2006 who had gone by car in autumn 2005 was tiny compared to the reduction of the number of passages over the charge cordon. At the most a reduction by 0.1% of the vehicle traffic over the cordon can be ascribed to expanded bus traffic.

As a result of the increase in patronage, crowding in public transport (measured by the number of standing passengers) increased to some extent in underground trains, while there was less crowding in commuter trains. Overall, congestion seems to be unchanged, partly due to the considerable capacity enhancement during the trial.

Accessibility to bus traffic to/from and in the inner city increased. Since inner city timetables were not adjusted to reduced congestion during the trial period, improved accessibility did not significantly shorten the travel times of inner city buses. However, there are signs that punctuality improved. Buses crossing the cordon that do not have fixed time tables once they have passed the cordon experienced considerably shorter travel times.

7.1. The technical system

The technical system worked very well, both from a purely technical point of view and from an informational point of view; people knew what to do, how to pay, etc. Payment compliance was high, and the number of complaints was much lower than expected. On an average day in May 2006, 371,300 journeys took place over the charge cordon. Nineteen percent of passages were made with exempted vehicles (buses, taxis, etc.), and an additional 9% were exempted due to the "Lidingö exception". 267,500 passages were hence charged, resulting in 115,100 tax decisions (one tax decision was made per day and vehicle) and yielding toll revenues of SEK 3.2 million. Of the 115,100 daily tax decisions, only 100 were investigated by the Swedish Tax Agency and five were appealed. The Swedish Road Administration customer-service unit received on an average day in May 2200 calls, in contrast to an expected number of 30,000 calls. Based on this, our assessment is that the system and the information generally worked well from a user's perspective.

Studies of business companies' attitudes showed that many were having problems with the administration of the charges. The systems for bookkeeping and keeping track of vehicles were not well designed for the business needs, especially not initially. This therefore will be changed when the system is restarted in the summer of 2007.

8. Economic effects

8.1. Effects on location and regional economy

The regional economy can be affected both in the short and the long-term. The effects on the economy depend to a large degree on whether, and in what way, the congestion tax is returned to the region. The effects of the Stockholm Trial on the economy have been investigated in several different studies, including a study on regional economic effects (Inregia, 2006).

The model calculations of the changed attractiveness of different areas show changes in various variables that are small in comparison to changes invoked by the pressure from a growing number of citizens and workplaces in the region. Even the influence on house prices is not of great significance. The long-term effects according to the model are not greater than the normal price variations between two quarters. The calculated effects are very sensitive to the choice of some model parameters, in particular the value of time.

8.2. Effects on retail

Based on the experiences from London, there were concerns that retail inside the cordon would be adversely affected (see Quddus et al., 2007 for a recent evaluation). However, the studies made during the Stockholm trial of retail markets were not able to show any effects of the congestion charges (see also the study by Daunfelt et al. (2009)). For example, a survey in shopping centres, malls and department stores shows that shopping for durable goods developed at the same rate as in the rest of the country. The same holds for other retail sectors.

A major reason for the absence of impacts on the retail sector strong enough to be detected is that the effects of the congestion tax on average disposable income were small, around one-tenth of a percent.

8.3. Cost-benefit analysis

A comprehensive cost-benefit analysis (Eliasson, forthcoming) performed on the basis of the measured result of the trial shows that the toll system yields a considerable social surplus net of investment and operational costs. A permanent congestion tax system is calculated to yield an annual social surplus of approximately SEK 650 million net of operation costs but not counting investment and startup costs of around 1900 million SEK. The social surplus pay-off time is estimated to 4 years. Increased bus traffic was found to be socially unprofitable. Benefits were calculated to SEK 180 million per year, compared to an operation costs of SEK 340 million per year.

9. Attitudes and opinions

9.1. Attitudes before and during the trail

Before the trial started, the general opinion was negative to both the trial as such, and to congestion charges in general. However attitudes of the general public and of business (separate business attitude surveys were conducted) became more positive once the charges were in place.

In autumn 2005 a majority (55%) of the residents in the metropolitan area (Stockholm county) stated that they found it to be a "very or rather bad decision" to conduct a trial (City of Stockholm, 2006b). After the toll was introduced, this percentage fell continuously. In April 2006 the majority had shifted, with 53% of the county population now stating that the trial was a "very or rather good decision" (City of Stockholm, 2006b). Similar trends – from different baselines – were found for all investigated sub-populations.

Residents living inside the cordon were more positive towards the trial than people living elsewhere in the region, throughout the investigated period. In April 2006, 58% of inner city residents found the trial to be a "very/rather good decision" (City of Stockholm, 2006b). The corresponding share for those living in municipalities just outside city boundaries, (at a typical distance to cordon of 10 km) was 47%. This was despite the fact that inner city residents on average experienced *smaller* reductions in travel time, and paid *more* charges, than people living in other areas (Eliasson and Levander, 2006)

This difference may suggest that some benefits were underestimated in the social benefit-cost analysis. Possibly, residents in the inner city who are non-frequent drivers put an additional value to reduced congestion above the value of their actual time gains (for instance, an option value reflecting the enhancement of the modal-choice set accomplished by less congestion). Also, previous studies have found that positive effects of road pricing on environment and safety are important factors affecting public acceptance of road pricing schemes (Jaensirisak et al., 2005) and such effects may have been more noticeable to inner city residents than to suburban commuters to the inner city.

9.2. The referendum

The Stockholm trial was followed by referenda in the municipality of Stockholm city and in about half of the neighbouring municipalities. Initially, only the Stockholm city municipality was planning a referendum. (The city of Stockholm is by far the largest municipality, accounting for almost half of the inhabitants of the county of Stockholm – the rest of the population is divided into 25 other municipalities. Two thirds of the Stockholm city inhabitants live inside the cordon, the remaining third outside.) In the autumn of 2005, opponents to road tolls suggested that also surrounding municipalities should arrange referenda. The cordon lies entirely within the city's boundaries, and since municipalities have responsibility for "local transport and roads", the city argued that it was entirely up to it to decide about the charges.

However, several surrounding municipalities, most vocally those governed by liberal/conservative majorities, argued that the issue affected their inhabitants as much as it affected the inhabitants of the city (which was not entirely true, judging from traffic and travel survey data). In the end, 14 surrounding municipalities arranged referenda of their own. This included all municipalities governed by liberal/conservative majorities, while most municipalities governed by social democratic/green majorities decided against arranging referenda. The municipalities that went ahead with referenda were also those with the strongest opinion against charges.

The referendum in the city of Stockholm ended with a majority for keeping the charges (53% yes, 47% no (not counting blank or invalid votes)). The referenda in the neighbouring municipalities (accounting for around a quarter of the county inhabitants) ended with a majority against (40% yes, 60% no). Adding all votes up, a majority of the voters were against (48% yes, 52% no) – but then, the results could be viewed as a bit skewed, since most of the municipalities where polls showed a majority for the charges did not arrange a referendum at all, instead declaring that it was up to the City of Stockholm to decide.

The results of these referenda were thus difficult to interpret. The legal power over the charges lies with the national government (since it is a tax from a legal point of view, and municipalities are only allowed to tax its own inhabitants). It was at the outset unclear how the national government should interpret the result. The political debate over road tolls changed visibly during the trial. Before the trial, the liberal and conservative opposition parties in Stockholm hoped that the strong opinion against tolls would help them to win the next election, while the ruling social democrat city governments for the same reasons tried to distance itself, suggesting that the referendum provided a way for voters to reject road tolls and still vote for the social democrats. But as the public opinion changed during the trial, liberals and conservatives tended to stop talking about this issue (although this differed between the parties), while the social democrats turned more eager to take it up.

The referenda coincided with the general elections, which resulted in new liberal/conservative majorities at the national, county and city government levels. After pondering how to interpret the outcome of the referendums for 2 weeks, the new national government decided that congestion charges was to be reintroduced during 2007 (later decided to start in July), but that revenues should be earmarked for road investments, in an effort to compensate negative impacts on the municipalities surrounding the city of Stockholm.

Today, the congestion tax of Stockholm has become permanent. The design of the current system resembles closely that of the trial period. The tax rates are the same, however, the month of July is exempted. Also, the congestion tax is made deductible from the income tax, which may reduce the effective tax rate by up to 57% (but on average probably much less). The tax exemption for taxis has been abolished, while it is to be kept for eco-cars for a period of 5 years.

10. Conclusions

10.1. Comparison with other measures and investments

A first result of the Stockholm trial is that vehicle traffic decreases as driving is made more expensive by road tolls. Another and more interesting result concerns the magnitude of this change. The trial showed that the tolls resulted in reductions of traffic congestion and travel times that were large compared to the expected effects of other measures that are discussed in Stockholm traffic:

- A new Eastern bypass is estimated to reduce the number of vehicles passing over inner city bridges by approximately 14% (Markstedt et al., 2005).
- A new Western bypass is estimated to reduce traffic across inner city bridges by 11% (Eliasson et al., 2006).
- If public transport was made free-of-charge in the Stockholm county, this is estimated to reduce vehicle kilometres travelled in the county by 3% (Stockholm Transport, 2006b).

Besides being more effective than these measures in reducing inner city congestion, the environmental effects and the public finance aspects of road tolls differ substantially different from these measures. The Western bypass is estimated to cost SEK 25 billion, the Eastern bypass SEK 15–20 billion, while free public transport reduces public revenue by SEK 5 billion per year. Since the road tolls result in a financial surplus of SEK 500–600 million each year (after operational costs have been deducted), it is unreasonable to set up these investments *against* toll. Both financially and in a traffic perspective, it is more natural to see them as complements.

The environmental side effects of the road tolls are worth stressing. Cities today face great difficulties in dealing with both congestion and pollution such as carbon-dioxide emissions. Road tolls deal with both problems simultaneously.

10.2. The significance of the Stockholm trial

We briefly summarise what we learned from the Stockholm trial:

Improvements in travel times were large enough to be perceived by the general public. This was pivotal to the change of the public opinion. Surprisingly, travel time improvements occurred also far from the inner city.

It was a bit of a surprise that no more than about half of the displaced motorists changed to public transport. Travel patterns are adjusted in subtle ways. "Moving congestion" – to other roads or to the public transit – was less of a problem than anticipated.

Adjustments took place quickly. Before the trial, especially when it became clear that the trial period would be reduced to 6 months; there was some doubt as to whether any traffic reduction would actually take place during a brief and transient trial. Could it be that people would decide to 'sit out' the trial period without changing their travel habits? We now know that the trial indeed had an immediate effect.

The effects on air-borne pollution were a little less than proportional to the decrease of traffic volume. Especially important environmental side-effects of the congestion tax were the reductions of exposure to particles in areas with dense daytime population and of carbon-dioxide emissions.

The Stockholm Trial provides interesting insights into road toll system design. Traffic economists have long discussed to what extent a charge-zone toll of the kind used in Stockholm is sufficient for controlling traffic in an entire city. Traffic relations change from street to street and from minute to minute. As the charge-zone of Stockholm was large, there was concern that compensatory increase of traffic inside the zone would mitigate or even eliminate the reduction of congestion from the cordon toll. Alternative solutions with multiple zones were therefore discussed prior to the trial. None of the previously existing road toll systems threw much light on this question. In London, only the city centre is included, in Singapore access to cars is also regulated and in Oslo and Bergen the system is designed to affect traffic as little as possible. The Stockholm Trial shows that a simple charge-zone toll can create significant effects within an area covering most parts of the inner city.

The trial also demonstrated that enhanced public transport in itself cannot alone be used as a means of reducing congestion in Stockholm; probably because public transport is well developed already. Improved public transport including several new bus lines did not appear to result in any measurable reduction in vehicle traffic, despite SL registering increased travel on its network. The well-functioning public transport system, however, made it possible to manage the large number of motorists that changed to public transport when road tolls were introduced. Public transit in Stockholm offered a convenient alternative to many car commuters of Stockholm.[10]

References

Armelius, H., Hultkrantz, L., 2006. The politico-economic link between public transport and road pricing: an ex-ante study of the Stockholm road-pricing trial. Transport Policy 13 (2), 162–172.

Carlsson, A. Hammarström, U., Yahya M.-R., Jonsson, P., 2006. Utvärdering av Stockholmsförsökets effekter på vägtrafikens avgasemissioner. Report to the City of Stockholm. VTI report.

City of Stockholm, 2003. Decision from the Mayor's office [Kommunstyrelsen] June 2, 2003, Decision no. 2003:50 RI.

City of Stockholm, 2006a. Information about the Stockholm trial. Available at <http://www.stockholmsforsoket.se/templates/page.aspx?id=2431>.

City of Stockholm, 2006b. Facts and results from the Stockholm Trials. Final version – December 2006 Available at <http://www.stockholmsforsoket.se/upload/Sammanfattningar/English/Final%20Report_The%20Stockholm%20Trial.pdf>.

Daunfelt, S.O., Rudholm, N., Rämne, U., 2009. Road pricing and Retail Revenues: Results from the Stockholm Road Pricing Trial. Transportation Research A 43 (3), 306–309.

Eliasson, J., Lindqvist, E., Svahlgård, S., 2003a. Miljöavgifter i Stockholm. Analys av olika förslag till utformning – Huvudrapport. [Environmental charges in Stockholm. Analysis of different proposed designs – Main report.] Transek report, December.

Eliasson, J., Lundberg, M., Svahlgård, S., 2003b. Miljöavgifter i Stockholm. Analys av nuvarande förslag till utformning – Sammanfattning. [Environmental charges in Stockholm. Analysis of the currently proposed designs – Summary.] Transek report, December.

Eliasson, J., Svahlgård, S., Dillén, J., 2004. Miljöavgifter i Stockholm. Effekter av Kommunstyrelsens förslag till utformning december 2003. [Environmental charges in Stockholm. Effects by the design proposed by the Mayor's office December 2003]. Transek report 2004:7.

Eliasson, J., Svahlgård, S., Lindqvist, E., Andersson, W., Anderssson, M., 2006. Samhällsekonomiska kalkyler för Nordsydliga förbindelser i Stockholm. [Cost-benefit analysis of the Western bypass]. Transek report 2006:18, available at <http://www.vv.se/templates/page3_8962.aspx>.

Eliasson, J., Levander, A., 2006. Equity Effects of the Stockholm Trial. Transek report 2006:36. Available at <http://www.stockholmsforsoket.se/templates/page.aspx?id=12555>.

Eliasson, J., forthcoming. A cost-benefit analysis of the Stockholm congestion charging system. Transportation Research Part A.

Elvik, R., Borger Mysen, A., Vaa, Tr., 1997. Trafikksikkerhetshåndbok. Oversikt over virkninger, kostnader og offentlige ansvarsforhold for 124 trafikksikkerhetstiltak (3:e upplagan). Transportøkonomisk institutt, TÖI. Oslo.

Ericsson, E., 2001. Independent driving pattern factors and their influence on fuel-use and exhaust emission factors. Transportation Research Part D 6, 325–345.

Forsberg, B., Burman, L., Johansson, C., 2006. Stockholmsförsöket har folkhälsopotential. Läkartidningen No. 50–52, vol. 103. <http://ltarkiv.lakartidningen.se>.

Gudmundsson, H., Ericsson, E., Beser Hugosson, M., Smidfelt Rosqvist, L., 2009. The role of decision support in the implementation process of the Stockholm congestion charges. Transportation Research Part A 43 (3), 258–268.

Inregia, 2006. Regionalekonomisk utvärdering av Stockholmsförsöket. Report to the City of Stockholm.

Jaensirisak, S., Wardman, M., May, A.D., 2005. Explaining variations in public acceptability of road pricing schemes. Journal of Transport Economics and Policy 2 (39), 127–153.

Kottenhoff, K., Brundell Freij, K., 2009. The role of public transport for feasibility and acceptability of congestion charging – the case of Stockholm. Transportation Research Part A 43 (3), 297–305.

[10] On the possible role of public transport to public opinion acceptance of congestion charges, see Armelius and Hultkrantz (2006).

Markstedt, A., Scheele, S., Eliasson, J., 2005. Östliga förbindelser inom Stockholm stad och Nacka kommun. Förstudie – Preliminära trafikanalyser. [Eastern bypass proposals within Stockholm and Nacka. Prestudy – Preliminary traffid analyses.] WSP report 2005-01-27, available at <http://www.vv.se/templates/page3____8467.aspx>.

Nafstad, P., Haheim, L.L., Wisloff, T., Gram, F., Oftedal, B., Holme, I., 2004. Urban air pollution and mortality in a cohort of Norwegian men. Environ Health Perspect 112 (5), 610–615.

G. Nilsson, 2000. ''Hastighetsförändringar och trafiksäkerhetseffekter'' VTI notat 76-2000, The Swedish National Road and Transport Research Institute VTI.

Quddus, M.A., Bell, G.H., Schmöcker, J.-D., Fonzone, A., 2007. The impact of the congestion charge on the retail business in London: an econometric analysis. Transport Policy 14, 433–444.

SLB Analys, 2006. The Stockholm Trial. Effects on air quality and health. City of Stockholm Environment and Health Administration. SLB report 4:2006. <http://www.slb.nu>.

Smidfelt Rosqvist L., 2003. On the relations between Driving Patterns, Exhaust emissions and Network Characteristics in Urban Driving. ISSN 1404-272X Bulletin – Lund University, 213.

Stockholm Transport, 2006a. SL's contribution to the Stockholm trial – effects on SL's services, travellers' demand and attitudes, December 2006, ISBN 91-633-0072-9.

Stockholm Transport, 2006b. Fyra prisstrategier. SL Plan 2006:2.

Transek, 2006a. Utvärdering av effekter på distributions- och renhållningstransporter. Report to the City of Stockholm.

Transek, 2006b. Invånarnas upplevelser av stadsmiljön före och under Stockholmsförsöket. Report to the City of Stockholm.

Transport for London, 2003. Congestion charging: six months on. Report from Mayor of London, October 2003.

Trivector, 2006a. Changes in travel habits in Stockholm County. Effects of the Stockholm trail. Report to the City of Stockholm. Trivector report 2006:67.

Trivector, 2006b. Trafiksäkerheten i Stockholms län. Effekter av Stockholmsförsöket, slutrapport. Trivector report 2006:49.