Scandinavian Toll Cordons' Effects: Adaptations, Equity and Attitudes

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Abstract
Roadway tolls are seeing increasing use in metropolitan areas worldwide, motivated first by increasing reliance on user fees to finance maintenance and expansion of transport infrastructure, and second by a strategy of reducing congestion externalities by discouraging car use in peak periods. In Scandinavia in particular, roadway tolls have been tested and permanently implemented in more cities than in any other region around the world. Despite the large body of evidence directly after these implementations, there remain several issues related to the effects of roadway tolls that are unexplored, not only in the Scandinavian cases but also abroad. This report documents the results of a research project intended to help fill these gaps. Our main contributions to the literature are in three broad areas: 1) travel adaptations patterns and their underlying explanations; 2) effects of tolling on location patterns and on telecommuting; and 3) explanations for the varying levels of acceptability of tolling schemes across time and in different locations.

Keywords: tolls, road pricing, equity, adaptation, acceptance, attitudes

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Final Report for BISEK: Bilens sociala och ekonomiska betydelse

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1 Introduction

Roadway tolls are seeing increasing use in metropolitan areas worldwide, motivated first by increasing reliance on user fees to finance maintenance and expansion of transport infrastructure, and second by a strategy of reducing congestion externalities by discouraging car use in peak periods. In Scandinavia in particular, roadway tolls have been tested and permanently implemented in more cities than in any other region around the world. In the earliest cases, Norway's *bompeng* (turnpike toll) system was implemented in Bergen (1986) as a means to raise revenue for roadway infrastructure. Similar toll systems were later introduced in Oslo (1990), Trondheim (1991), and Stavanger (2001).

In more recent years, the Swedish cities of Stockholm (2006) and Gothenburg (2013) have piloted and implemented congestion pricing schemes, known as *trängselskatter* (congestion taxes). These Swedish implementations have had policy goals ranging from the mitigation of environmental effects of transport, to the reduction of congestion delays, to raising revenue for roadway and public transport infrastructure. Although the stated emphasis on these policy goals has varied over time, the designs of these systems have so far been relatively stable: they are both based on a cordon-based bidirectional toll that varies by time of day on a fixed schedule, which is loosely based on temporal patterns of congestion. This is perhaps due a persistent emphasis on reducing congestion in urban centres, which makes a toll ring a relatively efficient configuration.

While these experiences with roadway tolls have largely borne out expectations of revenue generation and congestion mitigation, the overall effects of such tolls remain uncertain with respect to their distributional effects on different segments of the local population. Starting with the works of Richardson (1974) and Layard (1977), congestion pricing has been criticized for its so-called "equity effects", in other words bringing regressive effects at least on the population of frequent road users, and sometimes on the population overall. By equity effects we mean that the effects of the system are distributed across population sub-groups in a manner that is in some way undesirable from a point of view of justice and fairness. In addressing equity effects, it is necessary to be more specific about what is distributed. In prior equity literature, focus is mostly on three kinds of expressions of effects: 1) travel responses, referred to principally as adaptation patterns; 2) welfare effects, being a composite measure of total well-being as a consequence of policies in place and accounting for behavioural responses; and 3) stated attitudes toward the policy in question. In this project we focus on the first and third of these.

Indeed much prior research has studied the equity effects of tolls in these Scandinavian implementations, finding more nuance than the theoretical work of the 1970's could produce, including Eliasson & Levander (2006), Ramjerdi et al (2008), Eliasson et al (2009), Karlström & Franklin (2009), Franklin et al (2009), and Börjesson et al (2012). Broadly speaking, these found that equity effects of these toll systems exist, but that they were less pronounced than expected.

Despite the large body of evidence directly after these implementations, there remain several issues related to the effects of roadway tolls that are unexplored, not only in the Scandinavian cases but also abroad. This report documents the results of a research project intended to help fill these gaps. The chapters are arranged after the project's work packages, each of which focuses on a group of research questions posed for one or several of four Scandinavian implementations: Oslo, Trondheim, Stockholm, and Gothenburg. Of these, Gothenburg and Trondheim receive the greatest emphasis and Oslo the least, owing to differences in data available for analysis.

1.1 Past Literature

Prior literature on the equity, adaptation, and attitudes effects of cordon tolls can be organized along two dimensions. Central questions tend to vary along a first dimension:

a. Estimating utilitarian welfare effects overall,

b. Assessing the vertical and/or horizontal equity of cordon tolls' direct impacts (e.g. who pays, who adapts, etc.),

c. Assessing vertical and/or horizontal equity aspects of welfare effects,

d. Assessing attitudes and popular acceptability, and

e. Attitudes with respect to principles of fairness.

Along a second dimension, several types of analysis methods are applied:

1. Theoretical and conceptual frameworks for cordon tolls,
2. Computer simulations of cordon tolls' effects,
3. Empirical studies of cordon tolls' real effects, and
4. Opinion studies on cordon toll schemes (both real and hypothetical).

Some of the most prominent research contributions, with a particular emphasis on recent and Scandinavian literature, are shown in Table 1.1, using these two dimensions of classification: the five types of central questions are shown as the four rows, and the four types of analyses are shown in the four columns.

As well-documented by Lindsey (2006) in a review article, the theoretical and conceptual bases for examining the equity and fairness implications of tolling systems stem largely from the basic economic argument for tolling in the first place, as first developed by Pigou (1920) and Knight (1924), essentially on grounds of welfare maximization. However, not until Vickrey's analyses using the so-called bottleneck model did the idea generate strong traction among active economic study (Vickrey 1968; Vickrey 1969). This soon led to interest in equity questions, with some, such as Foster (1974a; 1974b), arguing that the wealthier would be subject to roadway tolls; while others argued that tolls would be generally regressive: Richardson (1974) on the basis of toll-to-income ratio, and Layard (1977) and Glazer (1981) on the basis of higher value-of-time of the wealthy. The importance of toll revenue redistribution was emphasized in such literature, but not at all resolved, and its role continues to be invoked in more recent literature (e.g. Eliasson and Mattsson 2000).

Parallel to the economic debates about tolling's equity effects, more pragmatic approaches emerged in the 1990s and forward. Studies by Giuliano (1994) and Teubel (2000) put more emphasis on comparing adaptation patterns of different population groups, rather than focusing on the estimated welfare effects per group. Moreover, owing largely to the discrepancy between favourable economic arguments and the real-world resistance to congestion pricing, the concept of *acceptability* began to gain traction, often used as catch-all term for whether the state or the population at-large, either for selfish or altruistic reasons, found tolls to be a favourable improvement. A range of contributions to the conceptual basis for acceptability research can be found in Schade & Schlag (2003), with the motivating arguments drawn from fairness principles, psychological theory, and political economy.

Table 1.1. Selected Literature on Cordon Tolls' Equity, Adaptation, and Acceptability Effects

	1. Theory & Concepts	**2. Model Simulation**	**3. Empirical Evidence**	**4. Opinion Surveys**
a. Welfare	Arnott et al (1994)	Teubel (2000); Vold et al (2001); Safirova et al (2003); Odeck et al (2003)	Wilson (1988); Santos (2007)	
b. Equity of Adaptation	Steg & Schuitema (2007); Tennøy et al (2012)	Giuliano (1994); Teubel (2000); Eliasson & Mattsson (2000)	Smidfeldt-Rosqvist (2006); Karlström & Franklin (2009); Göteborgs stad (2013)	
c. Equity of Welfare	Foster (1974a; 1974b); Richardson (1974); Layard (1977); Glazer (1981); Small (1983); Santos & Rojey (2004); Ramjerdi (2006); Ramjerdi & Minken (2008); Aretun & Hansson (2012)	Vold et al (2001); Safirova et al (2003); Eliasson & Mattsson (2004); Franklin (2006); Schweitzer & Taylor (2008); Bureau & Glachant (2008)	Eliasson & Levander (2006); Ramjerdi (2006); Santos (2008); Karlström & Franklin (2009); Franklin et al (2009)	
d. Attitudes and Acceptability	Viegas (2001); Schade & Schlag (2003); Raux & Souche (2004)	Giuliano (1992); Westin et al (2012)	Odeck & Bråthen (1997; 1998); Ison & Rye (2005); Raux et al (2009); Börjesson et al (2012)	Jakobsson et al (2000); Gaunt et al (2007); Schuitema et al (2010); Hårsman & Quigley (2010); Eliasson & Jonsson (2011)
e. Attitudes and Fairness	Crozet & Marlot (2001)		Langmyhr (1997)	Jakobsson et al (2000); Hamilton (2012); Börjesson et al (2012)

Even as the theoretical, conceptual, and modelling approaches continued to develop, some real-world cordon-style toll systems actually began to be implemented, with the earliest set in Singapore (1975, and significantly upgraded in 1998), followed by the Norwegian cities of Bergen (1986), Oslo (1990) and Trondheim (1991). London implemented its area-wide congestion charging in 2003, and in Sweden, Stockholm introduced congestion charging first in 2006, followed in Gothenburg in 2013. Milan has implemented two variants of cordon tolls in 2008 and 2012, respectively. Some smaller cities, such as Valetta, Malta and Durham, United Kingdom, have also experimented with congestion pricing on roads. The slow proliferation of tolls schemes has allowed a modest accumulation of empirical evidence about their effects.

Many of these empirical studies have found the effects in reality to be far murkier than in theory. Wilson (1988) found the welfare effects of Singapore's tolls to be far from certain, but more than likely positive. Santos (2008) found that London's congestion charges were effective at its stated policy goal of reducing congestion, but that it was suboptimal in that cars were overcharged. When attempting to explain why London's charges were accepted while Hong Kong's and Cambridge's were not, Ison & Rye (2005) found that no one issue could be singled out, but rather that lack of severe congestion, privacy, and political communication may have contributed.

1.2 Past Evidence on Equity and Acceptance Aspects of Cordon Tolls in Four Scandinavian Cities

Specifically relevant to this project is the prior evidence on the effects of the Scandinavian cordon tolls on different demographic groups and on attitudes and acceptance. However, it is worth pointing out that the past literature has been far from harmonious in its analysis approaches and methods, and consequently the past findings for different cities have varying character.

1.2.1 Oslo

Starting with the Norwegian toll rings, Odeck and Bråthen (1997; 1998) analysed interview data on Oslo's toll ring, finding that despite majority opposition to the toll ring, the gap between supporters and opponents shrank gradually from 1989 to 1998.

Two modelling studies have also been conducted in the context of Oslo's toll ring. The first of these produced forecasts of the effects of modifying Oslo's toll ring from fixed fee levels to variable fees to combat congestion, with the result that this would lead to significant socio-economic benefits and improved environmental effects (James Odeck, Rekdal, and Norrmann Hamre 2003).

Later, Ramjerdi (2006), complementing observations with model simulation, illustrated that the equity effects in Oslo varied depending on the equity indicator applied, as well as on the level of spatial aggregation. Most indicators of spatial equity across 10 zones showed that the policy scenario worsened equality, compared to the reference scenario. Yet, the differences are vanishingly small, and moreover, a similar analysis on a more disaggregate spatial zone system showed the opposite results for a series of equity measures based on statistical distribution measure. We can see from this that there are some indications of increasing inequality due to Oslo's toll ring, but that these findings are not conclusive.

1.2.2 Trondheim

When Trondheim introduced road tolls in 1992, the same pattern was seen as was in Oslo, with a shrinking opposition to the tolls (James Odeck and Bråthen 2002). This pattern was also found in Bergen in the same study.

Meanwhile, evidentiary studies of equity effects in Trondheim are very limited, but one study of the effects of *removing* the previous toll scheme in 2005 concluded that the equity effects had been very small, since there was little evidence that any particular demographic group had been especially "priced-off" by the tolls, compared to after the tolls were removed (Meland, Tretvik, and Welde 2010). To our knowledge, no study of the new toll scheme's equity effects has so far been conducted.

1.2.3 Stockholm

The findings in Stockholm were that most drivers were rather irregular toll-payers due to variation in travel behaviour, and that the variations in adaptation patterns by gender and income group were quite small compared to variation within these groups (Eliasson and Levander 2006). The estimated welfare effects (disregarding revenue recycling) by income group were overall more negative for higher income groups than for lower income groups, mainly due to the amounts of tax paid, even though these groups also gained the most from reduced travel times. Surprisingly, an indicator of adaptation costs[1] neither increased nor decreased linearly with income, but instead showed an irregular pattern.

In addition to the above findings, the welfare effects for subgroups that did and did not adapt to the tolls were not systematically correlated with income and constituted a nearly negligible portion of income (Franklin, Eliasson, and Karlström 2009).

1.2.4 Gothenburg

The Gothenburg tolls were implemented only in 2013; no findings related to adaptation patterns on different demographic groups had yet been published when this study began. However, some of the authors of this study have also been involved in the official evaluation of the Gothenburg charges (Göteborgs stad 2013), which compares several demographic groups' shares both of the total trips across the toll cordon by all modes, and of the total trips by toll-paying automobile. These findings illustrate that despite a greater share of males commuting across the cordon than the share of females, this difference was less when looking only at car trips. When comparing age groups, the youngest had the greatest shares across the cordon for car trips, but the least shares across the cordon for all modes. The results by income were rather uneven by group, which seemed to reflect the earlier welfare effect estimates in Stockholm. These results do not, however, indicate the degree to which each demographic group *changed* their travel behaviour from 2012 to 2013.

1.2.5 Other Cities

Urban toll rings also exist in further locations in Norway, for example in Bergen, Stavanger, Kristiansand, Tønsberg and Namsos. Some of these are also addressed in the literature above, but evidence is more limited in these cases compared to the four larger cities highlighted in this study.

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[1] Adaptation costs were taken to be half the avoided toll payments, which is based on the assumption that adaptation costs vary linearly across those who adapted, from nearly equal to the avoided toll payment, to nearly zero. This is a standard approach when using *rule-of-half* to measure welfare effects.

1.3 Main Findings

Our main contributions to the literature are in three broad areas: 1) travel adaptations patterns and their underlying explanations; 2) effects of tolling on location patterns and on telecommuting; and 3) explanations for the varying levels of acceptability of tolling schemes across time and in different locations.

1.3.1 Adaptation patterns and explanatory factors

The literature on adaptation patterns for different segments of the population has, up to now, focused on first-order associations – in other words, different groups have adapted in different ways, but for reasons that are entirely hidden – and nearly all studies focus on number of trips, mode choice, and route choice. A major contribution of this study is to assess adaptations in tour organization, which gives insights into how the remaining tolled trips are organised. In Chapter 3, we first confirm that for all demographic groups in Gothenburg and Stockholm, the primary mechanism of adapting to tolls is to change mode of travel, for example to public transport. Indeed, this is strongly consistent with prior findings, explaining roughly 33% of reduced toll crossing. We also find that up to 16% might be explained by increased car occupancy, although we cannot say whether this is from economisation within households or carpooling among co-workers. In addition, distinct from prior evidence, the results from Gothenburg suggest that travellers also reorganise their remaining trips across the cordon into longer tours, thereby reducing the number of crossings over the toll cordon both at the per-trip-level and at the per-tour-level.

The corresponding findings for Trondheim, from Chapter 6, are less clear due to seasonal effects, and as a consequence no clear conclusions could be drawn that mode choice was affected by the tolls. Similarly, trip frequencies could not be attributed specifically to the road tolls, since the reduction in trips across the cordon was no greater than the reduction in trips that did not cross the cordon. However, there are some indications that the time-differentiated tolls led to delayed departures in the evening peak, especially for discretionary trips.

Adaptation mechanisms were also studied in combination with a set of possible explanatory factors, as far as possible from the available data from Stockholm. In Chapter 5, we show that different population groups reduced their trips to different extents, but that these changes can only be marginally explained by differences in access to car, possession of a long-term public transport pass, and whether or not the commute trajectory requires crossing the toll cordon. Nonetheless, most of the studied factors had significant mediating effects between demographics and adaptation. As a consequence, there are indications that mediating factors in general can play an important role, but that the particular factors studied here were far from sufficient to explain the magnitude of differences between demographic groups. As suggested in Section 1.3.2 below, other possible factors might include the availability of telecommuting as a realistic option.

1.3.2 Effects on location patterns and telecommuting

Research on the effects of tolls on other kinds of choices besides travel behaviour, such as location choice and telecommuting, have been limited to modelling exercises (e.g. Safirova et al. 2003; Eliasson and Mattsson 2000). Ramjerdi (1994), based on a two-wave panel study that was conducted before and after the introduction of the toll scheme in Oslo in February 1990, suggests that the short term impact on the toll on home or work locations was not present. The transaction cost of changing home or work location is much larger than the toll cost. In the long term, a household might consider toll costs if due to other reasons (e.g., changes due to lifecycle, change in income, etc.) a change in housing location is on the agenda. Ramjerdi also shows that the impact of the scheme on the destination choices has been statistically significant for the locations of services and businesses that were closer to the toll ring. However, the extent of the impacts was quite small.

In Chapter 6, we find using a survey of Trondheim residents that tolls played a relatively small roll in expected home and work location choices in either the medium- and long-term (about 11% of respondents), and nearly zero roll in past moves (about 2% of respondents). This is rather unsurprising, considering the variety of other factors that are thought to more strongly influence location choice. On the other hand, according to the survey results in Trondheim, avoiding the tolls motivated 18% of respondents to telecommute. These were disproportionately high-income respondents. This suggests that the connection between tolling and telecommuting is a worthwhile avenue of further research.

1.3.3 Attitudes and acceptability of congestion tolls

Our research has contributed significantly to the growing field of acceptability of tolling by providing important empirical evidence and by connecting attitudes to principles of fairness. For example, in Chapter 3, we found similar patterns of opposition declining sometime after implementation of most, but not all, toll systems, although opposition in Trondheim and Oslo tended to remain a majority, even after these declines. Moreover, the pre-implementation opposition in Oslo in 2014 was larger than the pre-implementation opposition in 2005, suggesting that despite declines after implementation, repeated tolling initiatives may have a fatiguing effect on popular support. This is perhaps consistent with the most common reason for opposition, according to the survey: the perception of already paying enough in taxes and fees.

Secondly, in Chapter 7, we show that in Gothenburg, improving acceptance toward congestion tolls after implementation were best explained by so-called *status quo bias*, in which respondents are naturally inclined to prefer the current situation when asked the question. However, attitudes about fairness in general did not appear to be influenced by experiencing the congestion tolls in Gothenburg. Specifically, concerns about social equity were not strongly associated with attitudes about congestion tolls.

Across different cities, differences in attitudes toward congestion tolls seem to be partly explained by the share of the population actually paying tolls: for example, in Gothenburg a larger share drive and pay tolls, and a larger share seem to oppose the tolls. This seems to be strongly intertwined with the attractiveness of alternatives to paying the toll. In Gothenburg, compared to Stockholm, congestion tolls had a smaller effect on number of trips over the cordon, in percent reduction. Furthermore, stabilization took much longer in Gothenburg. Also, lower-income travellers in Gothenburg and Stockholm pay a higher proportion of their disposable incomes than higher-income travellers in congestion charges, even if higher-income travellers pay more in absolute terms. Moreover, higher-income travellers in Stockholm were found to have greater access to a company car, such that the marginal cost of trips across the cordon are normally not passed on to the individual, but held by the employer.

1.4 Policy Implications

The findings above bear out a suspicion that has long existed among road tolling proponents—namely, that individuals find a wide variety of approaches to adapt to tolls, certainly beyond the ways that most researchers are able to measure. In this case, both telecommuting and reorganized tours were associated with tolls in different case study cities. Importantly, a wider variety of adaptation mechanisms available implies a lesser burden of adaptation, since individuals thus have a wider variety of ways to optimize the second-best alternative, if the toll is too expensive. However, even as this study has expanded the kinds of adaptations identified, there remain many other kinds of adaptations that are either expensive to measure (e.g. frequency of certain trip purposes over longer periods of time) or nearly impossible to attribute to the road tolls as a cause (e.g. changing choice of destination for infrequent trips). This latter category also includes changes in home location, as found in the Trondheim survey.

At the same time, the findings related to acceptability in Gothenburg, Stockholm, and Oslo indicated the importance of *status quo bias*, in other words that resistance to a policy measure tends to be stronger before it is implemented, than after it is implemented; evidence of this trend in Trondheim is, however, limited to the 1991 implementation, and in both Oslo and Norway, even the reduced opposition remained a majority. Status quo bias may be attributable to the uncertainty associated with a proposed, but unimplemented policy, and perhaps also an exaggerated expectation of the impacts of a policy (both positive and negative), compared to the real impacts after implementation. This may also be associated with the above finding that people have more ways to adapt to a policy than researchers typically anticipate. The consequence is that the total effect of the policy change is less than we anticipated, and these adaptation responses might be so subtle and diffuse in the long-run that travellers forget that they adopted them, leading them to tolerate the new status quo more than they anticipated they would. Furthermore, this research has limitations in capturing the ways that the public and businesses adapt to a toll scheme, since data is usually limited to partial, cross-sectional data.

In summary, the implications for policy are threefold: 1) the average burden of adapting to a toll is probably less than previously thought, due to wider adaptation responses than accounted for in previous analyses; 2) the differences between demographic groups are often obscured by these complex adaptation mechanisms; and 3) the diffuse nature of these adaptation patterns can lead to travellers accepting tolls after implementation, more readily than prior indications might suggest.

It is tempting to think that these findings suggest policy-makers can simply force through a new or modified toll system, knowing that individuals will somehow cope with it and accept it, despite their stated resistance. However, this perhaps neglects two important societal principles, the first being proper public consultation before action, and the second being the maintenance of a just society even for individuals who are not vocal about their objections.

To serve the first goal, public servants should strive to not only present the proposed toll system design itself in public consultation settings, but also complement this with realistic analyses of the kinds of adaptations that have been seen in similar locations, modified appropriately for the local setting so that individuals can more readily imagine what the new *status quo post* might mean for themselves. In service to the second goal, the particular mechanics of the toll policy, in terms of types of vehicles affected, geographic configuration, and schedule of fee levels, should be analysed for the local population's geographic and demographic distribution, so that differences in ability to adapt, such as those found here, can be anticipated and used to possibly modify the design.

1.5 Future Research Needs

A number of research needs can be identified from the project's cumulative findings. First, the conclusions here are limited especially when it comes to identifying adaptation mechanisms, since the travel surveys conducted in all of the case cities were exclusively based on individuals and not whole households, and based on one day of travel rather than several days in a row. The first limitation makes it impossible to draw conclusions about how households distribute trips between family members, and the second makes it difficult to differentiate between the toll system's effects on the one hand and natural day-to-day variations in travel activities on the other. Future research would be enormously helped by more comprehensive travel surveys that take both of these considerations into account.

Second, there are several possible explanations for the differences in adjustments in the face of tolls in the different cities, such as between Gothenburg and Stockholm. We state four hypotheses that could be relevant for future research:

- People changed in the beginning and then switched back as they did not find a suitable alternative (e.g. lack of good public transport alternative). An investigation would likely require a multi-day panel study with intervals between waves of 3-6 months. In most cities, such a survey design is expensive and rarely conducted.
- People overestimated the negative effect of congestion charges and switched back when they realized that it was not as bad as expected. This hypothesis might require a survey of even shorter intervals, conducted during the first few months after a toll is introduced or modified, and the survey should measure "expectations" in a consistent way.
- The signal of the congestion charges affected behaviour. The congestion charges in Stockholm were promoted as an environmental measure. In Gothenburg the congestion charges were seen as a way to finance an infrastructure package. The environmental label of the congestion charging in Stockholm might work as a signal for a socially acceptable behaviour. Indeed, much ongoing research, both in Scandinavia and elsewhere, is looking further into the role of environmental identification, in affecting travel decisions.
- That long distance trips have to cross the cordon in Gothenburg, Oslo, and Trondheim whilst they can avoid the charges in Stockholm. Long distance trips are probably much less sensitive to the taxes, which could explain a part of the differences in effects between Stockholm and the other three cities.

The data on public acceptability of a toll scheme also show different results when contrasting Stockholm and Gothenburg against Oslo and Trondheim. While in Sweden public acceptability seems to increase after the introduction of a scheme, the data in in Norway does not support the Swedish phenomenon. Could cultural differences between Norway and Sweden be an explanation for the differences? Sweden is known for a higher degree of paternalism than Norway. Could this be the reason?

What are the factors (e.g., the perceived impacts of a policy) that would lead to an increase in policy acceptance, such as a toll scheme? How do different segments of the population (not only based on the observed demographic variables, but also based on their attitudes, habits, etc.) change their acceptance of, or attitudes towards, a toll scheme? Understanding these points could help planners to better persuade individuals to align their behaviours with the public interest. Application of more advanced econometrics such as latent class and latent variable models to appropriate data is a possibility now.

1.6 Organization of the Report

This final report continues with a Swedish-language translation of this introduction, in Chapter 2. The remainder of the report consists of a compilation of sub-reports for the individual work packages of the project. In each sub-report, we identify a series of central research questions and conclude with the findings related to those same questions. We begin with Chapter 3, which is drawn from Work Package 5 and provides a background of the four case cities and comparisons of both their designs and their overall effects on traffic. Next, Chapter 4 presents the first set of results of Work Package 2, comparing individuals' patterns of adaptation to the tolls in Gothenburg. Chapter 5 presents the remaining results from Work Package 2, examining mechanisms behind adaptation responses in Stockholm. In Chapter 6, we present the results of Work Package 3, which consist mainly of a survey of individuals' self-reported adaptation patterns in Trondheim and how these were related to the toll ring. Finally, in Chapter 7, the results from Work Package 4 analyse the patterns of acceptability of congestion pricing particularly in Gothenburg, and how this is related to questions of equity effects.

2 Inledning på svenska

Vägtullar används i allt högre utsträckning i storstadsområden världen över, motiverade i första hand av att städerna i ökad utsträckning förlitar sig på vägavgifter för att finansiera underhåll och utbyggnad av transportinfrastruktur och i andra hand av en strategi för att minska de externa effekterna av trängsel genom att motverka bilanvändning under rusningstrafik. I Skandinavien i synnerhet har vägtullar testats och införts permanent i fler städer än i någon annan region internationellt. I de tidigaste fallen infördes Norges *bompengsystem* (tullbelagda vägar) i Bergen (1986) som ett sätt att öka intäkterna för väginfrastruktur. Liknande vägtullsystem infördes senare i Oslo (1990), Trondheim (1991) och Stavanger (2001).

Under senare år har de svenska städerna Stockholm (2006) och Göteborg (2013) genomfört pilotprojekt kring och infört trängselavgifter, kallade *trängselskatter*. Dessa införanden i Sverige har haft politiska mål som omfattat alltifrån att dämpa transporternas miljöeffekter till att minska fördröjningarna till följd av trängsel till att öka intäkterna för väg- och kollektivtrafikinfrastruktur. Även om statens betonande av dessa politiska mål har varierat med tiden, har de här systemens utformning hittills varit relativt stabil: De bygger båda på en passagebaserad dubbelriktad tull som varierar beroende på tiden på dagen efter ett fast schema, som löst hänger samman med tidsmönster för trängsel.

Dessa försök med vägtullar har visserligen i hög grad bekräftat förväntningarna om generering av intäkter och dämpning av trängsel, men de övergripande effekterna av sådana tullar förblir osäkra när det gäller deras fördelningseffekter på olika segment av de omgivande befolkningarna. Kritiken mot trängselavgifter började i Richardsons (1974) och Layards (1977) arbeten, kritik som hävdar att de medför regressiva effekter åtminstone på populationen bestående av frekventa väganvändare, och ibland på befolkningen i sin helhet. Med fördelningseffekter menas att systemets effekter fördelas bland befolkningens olika grupper på ett sätt som inte är samhällsmässigt önskvärt enligt jämlikhets- och rättviseprinciper. När man diskuterar frågor kring fördelningseffekter, behövs en precisering av vad som egentligen fördelas. I tidigare litteratur läggs fokus huvudsakligen på tre typer av uttryck för effekter; 1) ändringar i resbeteende, ofta kallade för anpassningsmönster; 2) välfärdseffekter, som består av ett sammansatt mått för totala välbefinnande som följd av gällande politiken och med hänsyn till ändringar i beteende; och 3) angivna attityder mot åtgärden i fråga. I detta projekt lägger vi fokus på det förstnämnda samt det sistnämnda.

En stor mängd forskning har faktiskt studerat jämlikhetseffekterna av vägtullar i dessa införanden i Skandinavien och funnit en mer nyanserad verklighet än vad det teoretiska arbetet från 1970-talet kunde åstadkomma, däribland Eliasson och Levander (2006), Ramjerdi et al (2008), Eliasson et al (2009), Karlström och Franklin (2009), Franklin et al (2009) och Börjesson et al (2012). Generellt sett fann dessa att vägtullsystemen hade fördelningseffekter, men att de var mindre uttalade än förväntat.

Trots den stora mängden evidens direkt efter dessa införanden, återstår flera frågor relaterade till effekterna av vägtullar som ännu är outforskade, inte bara i de skandinaviska fallen, utan även utomlands. Denna rapport dokumenterar resultaten från ett forskningsprojekt avsett att bidra till att fylla de här tomrummen. Kapitlen är ordnade efter projektets arbetspaket, vart och ett med fokus på en samling forskningsfrågor som ställts för ett eller flera av fyra införanden i Skandinavien: Oslo, Trondheim, Stockholm och Göteborg. Bland dessa läggs mest betoning på Göteborg och Trondheim och minst betoning på Oslo, på grund av olikheter i tillgängliga datakällor för respektive region.

2.1 Tidigare litteratur

Den tidigare litteraturen kring jämlikhets- och anpassningseffekterna av vägtullar kan organiseras längs två dimensioner. Centrala forskningsfrågor kan grupperas efter den ena dimensionen:

a. uppskattning av nyttoinriktade välfärdseffekter,

b. utvärderingar av den vertikala och/eller horisontella jämlikheten hos passagebaserade vägtullars direkta effekter (t.ex. vem betalar, vem anpassar sig osv.),

c. utvärderingar av vertikala och/eller horisontella jämlikhetsaspekter av välfärdseffekter,

d. utvärderingar av den allmänna acceptansen, och

e. attityder gentemot rättviseprinciper.

Längs den andra dimensionen finns det flera typer av analyser:

1. teoretiska och konceptuella ramar för vägtullar,
2. datorsimuleringar av vägtullars effekter,
3. empiriska studier av de vägtullars effekter, och
4. opinionsundersökningar av vägtullssystem (både verkliga och hypotetiska).

Några av de mer framstående forskningsarbetena, med särskild tonvikt på ny och skandinavisk litteratur, återges i Table 2.1, baserat på dessa två klassificeringsdimensioner; de fem ovanstående typerna av forskningsfrågor visas som fem rader och de fyra typerna av analys visas som fyra kolumner.

Något som är väl dokumenterat i en litteraturgranskning av Lindsey (2006) är att de teoretiska och begreppsmässiga grunderna för att undersöka vägtullsystemens konsekvenser för jämlikhet och rättvisa i hög grad härrör från det grundläggande ekonomiska argumentet för vägtullar, som först utvecklades av Pigou (1920) och Knight (1924), främst grundat på välfärdsmaximering. Det var emellertid inte förrän Vickrey utförde analyser med den så kallade flaskhalsmodellen (*Bottleneck Model*) som tanken fick ett stort genomslag bland aktiva ekonomiska studier (Vickrey 1968; Vickrey 1969). Det här ledde snart till ett intresse för jämlikhetsfrågor, där vissa, t.ex. Foster (1974a; 1974b), hävdade att de mer förmögna skulle få betala vägtullar, medan andra hävdade att vägtullarna skulle vara allmänt regressiva: Richardson (1974) baserat på förhållandet mellan vägtull och inkomst och Layard (1977) och Glazer (1981) baserat på ett högre tidsvärde för de mer förmögna. I sådan litteratur betonades vikten av fördelning och återföring av intäkterna från vägtullar, men frågan löstes inte alls, och dess roll tas fortsatt upp i senare litteratur (e.g. Eliasson and Mattsson 2000).

Parallellt med de ekonomiska debatterna kring vägtullarnas jämlikhetseffekter växte mer pragmatiska tillvägagångssätt fram under 1990-talet och framåt. Studier genomförda av Giuliano (1994) och Teubel (2000) lägger större tonvikt på att jämföra olika befolkningsgruppers anpassningsmönster än på att undersöka uppskattade välfärdseffekter per grupp. Dessutom började begreppet *acceptans* att få genomslag, till stor del på grund av bristen på överensstämmelse mellan gynnsamma ekonomiska argument och den verkliga världens motstånd mot trängselavgifter, och användes ofta som en övergripande term för huruvida staten eller befolkningen i stort uppfattade vägtullar som en gynnsam förbättring, vare sig det var av själviska eller altruistiska skäl. En rad bidrag till den begreppsmässiga grunden för acceptansforskning återfinns i Schade och Schlag (2003), med motiverande argument tagna från rättviseprinciper, psykologisk teori och politisk ekonomi.

Table 2.1. Utvald litteratur om vägtullars fördelnings-, anpassnings-, och acceptanseffekter

	1. Teorier och koncept	**2. Modell-simuleringar**	**3. Empiriskt bevis**	**4. Opinions-undersökningar**
a. Välfärd	Arnott et al (1994)	Teubel (2000); Vold et al (2001); Safirova et al (2003); Odeck et al (2003)	Wilson (1988); Santos (2007)	
b. Fördelningar av anpassningar	Steg & Schuitema (2007); Tennøy et al (2012)	Giuliano (1994); Teubel (2000); Eliasson & Mattsson (2000)	Smidfeldt-Rosqvist (2006); Karlström & Franklin (2009); Göteborgs stad (2013)	
c. Fördelningar av välfärdseffekter	Foster (1974a; 1974b); Richardson (1974); Layard (1977); Glazer (1981); Small (1983); Santos & Rojey (2004); Ramjerdi (2006); Ramjerdi & Minken (2008); Aretun & Hansson (2012)	Vold et al (2001); Safirova et al (2003); Eliasson & Mattsson (2004); Franklin (2006); Schweitzer & Taylor (2008); Bureau & Glachant (2008)	Eliasson & Levander (2006); Ramjerdi (2006); Santos (2008); Karlström & Franklin (2009); Franklin et al (2009)	
d. Attityder och acceptans	Viegas (2001); Schade & Schlag (2003); Raux & Souche (2004)	Giuliano (1992); Westin et al (2012)	Odeck & Bråthen (1997; 1998); Ison & Rye (2005); Raux et al (2009); Börjesson et al (2012)	Jakobsson et al (2000); Gaunt et al (2007); Schuitema et al (2010); Hårsman & Quigley (2010); Eliasson & Jonsson (2011)
e. Attityder och rättvisa	Crozet & Marlot (2001)		Langmyhr (1997)	Jakobsson et al (2000); Hamilton (2012); Börjesson et al (2012)

Medan de teoretiska, begreppsmässiga och modelleringsbaserade metoderna fortsatte att utvecklas, började faktiskt ett antal verkliga passagebaserade vägtullsystem införas, varav det tidigaste fanns i Singapore (1975, med en betydande uppgradering år 1998), följt av de norska städerna Bergen (1986), Oslo (1990) och Trondheim (1991). London införde sina områdesomfattande trängselavgifter år 2003 och i Sverige infördes trängselavgifter först i Stockholm år 2006, följt av Göteborg år 2013. Milano införde två varianter av passagebaserade vägtullar år 2008 respektive 2012. Vissa mindre städer, som Valetta – Malta och Durham – Storbritannien, har också gjort försök med trängselavgifter på vägar. På grund av den långsamma spridningen av vägtullsystemen finns endast en blygsam samlad mängd empiriska bevis för deras effekter.

Många av dessa empiriska studier har funnit att effekterna i verkligheten varit mycket dunklare än i teorin. Wilson (1988) fann att välfärdseffekterna av Singapores vägtullar var långt ifrån säkra, men högst sannolikt positiva. Santos (2008) fann att Londons trängselavgifter uppfyllde sina angivna politiska mål att minska trängsel, men att de inte var optimala då bilarna var överbeskattade. När de försökte förklara varför Londons avgifter accepterades, medan Hongkongs och Cambridges inte godtogs, fann Ison och Rye (2005) att det inte gick att identifiera någon enstaka fråga, utan att bristen på trängsel, integritet och politisk kommunikation kan ha bidragit till skillnaden.

2.2 Tidigare evidens om fördelningseffekter och acceptans från fyra skandinaviska städer

Något som är särskilt relevant för detta projekt är tidigare evidens för effekterna av de skandinaviska passagebaserade vägtullarna på olika befolkningsgrupper. Det är emellertid värt att påpeka att den tidigare litteraturen har varit långt ifrån enhetlig när det gäller tillvägagångssätt och metoder för analys och att tidigare rön för olika städer följaktligen har skiftande karaktär.

2.2.1 Oslo

Med början i de norska tullringarna, analyserade Odeck och Bråthen (1997; 1998) intervjudata om Oslos bompeng och fann att, trots en majoritet för oppositionen till tullringen, gapet mellan förespråkare och motståndare gradvis minskade mellan 1989 och 1998.

Två modelleringsstudier har även gjorts av Oslos bompeng. Den första tog fram en prognos av effekterna av att ändra Oslos fasta avgiftsnivåer med varierande avgifter för att motverka trängsel. Utfallet blev att den skulle leda till signifikanta socioekonomiska vinster och förbättrade miljökonsekvenser (James Odeck, Rekdal, and Norrmann Hamre 2003).

Senare kompletterade Ramjerdi (2006) observationer med modellsimulering för att illustrera att jämlikhetseffekterna i Oslo varierade beroende på vilken jämlikhetsindikator som användes samt graden av rumslig aggregering. De flesta indikatorer för rumslig rättvisa i 10 olika zoner visade att policyscenariot försämrade rättvisan jämfört med referensscenariot. Dock är skillnaderna försvinnande små och dessutom visade en liknande analys av 49 zoner motsatta resultat för vissa indikatorer, såsom variationsbredd, relativ medelavvikelse och logaritmernas varians. Utifrån detta ser vi att det finns vissa tecken på tilltagande ojämlikhet på grund av Oslos vägtullsring, men resultaten gör det inte möjligt att dra några definitiva slutsatser.

2.2.2 Trondheim

När Trondheim införde vägavgifter 1992 upprepade sig mönster som sågs i Oslo, med minskande opposition (James Odeck and Bråthen 2002). Detta mönster fanns också i Bergen i samma studie.

Evidensstudierna av jämlikhetseffekterna i Trondheim är emellertid mycket begränsade, men en studie av effekterna av att *ta bort* det föregående vägtullsystemet år 2005 drog slutsatsen att jämlikhetseffekterna hade varit mycket små, eftersom det fanns lite evidens för att någon viss befolkningsgrupp hade utestängts särskilt av vägtullarna, jämfört med efter att vägtullarna hade tagits bort (Meland, Tretvik, and Welde 2010). Enligt vår kännedom har ingen studie av det nya vägtullsystemets jämlikhetseffekter ännu genomförts.

2.2.3 Stockholm

I Stockholm visade det sig att bilisterna i genomsnitt var ganska oregelbundna vägtullbetalare, på grund av variationer i resebeteendet, och att anpassningsmönstren per kön och inkomstgrupp var ganska svaga jämfört med variationen inom de här grupperna (Eliasson and Levander 2006). De uppskattade välfärdseffekterna (bortsett från återföring av skatteintäkter) per inkomstgrupp var överlag mer negativa för högre inkomstgrupper än för lägre inkomstgrupper, främst på grund av inbetalt skattebelopp, även om de här grupperna även fick den största nyttan av förkortade restider. Förvånande nog varken ökade eller minskade anpassningskostnaderna[2] linjärt med inkomst, utan uppvisade i stället ett oregelbundet mönster.

Utöver ovan nämnda fynd, var välfärdseffekterna för delgrupper som anpassade sig eller inte anpassade sig till vägtullarna inte systematiskt korrelerade till inkomst, och de utgjorde en nästan försumbar del av inkomsten (Franklin, Eliasson, and Karlström 2009).

2.2.4 Göteborg

Göteborg införde vägtullar först år 2013, så inga fynd beträffande olika befolkningsgruppers anpassningsmönster hade ännu publicerats när denna studie inleddes. Vissa av upphovsmännen till denna studie har emellertid även deltagit i den officiella utvärderingen av Göteborgs avgifter (Göteborgs stad 2013), som jämför flera befolkningsgruppers andelar både av de totala resorna genom vägtullspassagerna, med alla transportsätt, och av de totala resorna med vägtullsbetalande bil. Dessa fynd visar att trots en större andel män som pendlade över vägtullspassagerna jämfört med andelen kvinnor, var den här skillnaden mindre när man tittade enbart på resor med bil. Jämförelsen av åldersgrupper visade att de yngsta hade de största andelarna genom för bilresor genom vägtullspassagerna, men de minsta andelarna genom vägtullspassagerna för alla transportsätt. Resultaten var ganska ojämna per inkomstgrupp, vilket verkar återspegla de tidigare uppskattningarna av välfärdseffekter i Stockholm. Dessa resultat indikerar emellertid inte i vilken utsträckning varje befolkningsgrupp *förändrade* sitt resebeteende från 2012 till 2013, så de resultat som beskrivs längre fram i denna rapport är nya.

2.2.5 Övriga städer

Urbana passagebaserade vägtullar finns även i flera andra städer i Norge, så som Bergen, Stavanger, Kristiansand, Tønsberg och Namsos. Vissa av dessa omfattas i litteraturen som citeras ovan men beläggen är mycket mer begränsade jämfört med de fyra större städer som står i fokus i denna studie.

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[2] Anpassningskostnader beräknas som halva av beloppet avgifter som undvikas, vilket baseras på antagandet att anpassningskostnader varierar linjärt bland alla som anpassar sig, från drygt lika med hela summan avgifter som undvikas, till nästan noll. Detta är ett standardangreppssätt när man tillämpar den s k *rule-of-half*-metoden för att mäta välfärdseffekter.

2.3 Nya fynd

Våra huvudsakliga bidrag till litteraturen finns inom tre breda områden: 1) reseanpassningsmönster och deras underliggande förklaringar, 2) effekterna av vägtullar på ortsmönster och distansarbete, och 3) förklaringar till de varierande nivåerna av acceptans för vägtullsystem beroende på tid och plats.

2.3.1 Anpassningsmönster och orsaksfaktorer

Litteraturen kring anpassningsmönster för olika befolkningssegment har hittills lagt fokus på direkta samband – med andra ord har olika grupper anpassat sig på olika sätt, men av skäl som är helt dolda – och nästan alla studier lägger fokus på antal resor, val av transportsätt och val av rutt. Denna studie bidrar på ett betydelsefullt sätt genom att utvärdera anpassningarna i reseturers struktur, vilket leder till nya insikter i hur kvarstående resor över tullsnittet organiseras. I kapitel 3 bekräftar vi att för alla befolkningsgrupper i Göteborg och Stockholm är den huvudsakliga mekanismen för anpassning till vägtullar att byta transportsätt, främst till kollektivtrafiken. Detta är helt i linje med tidigare fynd, och förklarar ungefär 33% av minskningen i passager över snittet. Vidare finner vi att så många som 16% av minskade bilresor över snittet skulle kunna förklaras av ökad beläggning vid bilresor. Dock kan vi inte säga om detta är t ex på grund av effektivisering av hushållsresor eller på grund av ökad samåkning för medarbetare på samma arbetsplats. Till skillnad från tidigare evidens pekar emellertid resultaten från Göteborg på en betydande effekt på hur resenärerna organiserar sina resor i turer, för att minimera antalet genomfarter genom vägtullspassagerna.

Motsvarande resultat för Trondheim, ur kapitel 6, är mindre tydliga på grund av säsongseffekter, och som följd därav kunde det inte dras någon slutsats om att färdmedelsvalet påverkades av vägavgifterna. På liknande sätt kan antalet resor över snittet inte tillskrivas specifikt till vägtullar, eftersom minskningen i antal resor över snittet inte var större än minskningen av resor som inte korsar snittet. Det finns dock vissa tecken på att de tidsdifferentierade vägtullarna lett till försenade avgångar på under kvällsrusningen, särskilt för diskretionära resor.

Anpassningsmekanismerna studerades även i kombination med en uppsättning möjliga orsaksfaktorer, i den utsträckning som var möjlig med tillgängliga data i Stockholm. I kapitel 5 visar vi att olika befolkningsgrupper minskade sina resor i olika utsträckning, men att dessa ändringar bara marginellt kan förklaras av olikheter i tillgång till bil, ägarskap av ett periodkort för kollektivtrafik, eller huruvida pendlingvägen korsar snittet. Ändå hade de flesta av faktorerna i fråga signifikanta medierande effekter mellan demografiska egenskaper och anpassningsgrad. Som följd kan det konstateras att medierande faktorer allmänt spelar en viktig roll men att de specifika faktorer som undersöks här är långt ifrån tillräckliga för att förklara magnituden i skillnader mellan demografiska grupperingar. Som föreslås nedan i avsnitt 2.3.2 kan möjligheten för distansarbete utgör en sådan faktor.

2.3.2 Effekter på ortsmönster och distansarbete

Forskningen kring vägtullars effekter på andra typer av val, utöver resebeteendet, såsom val av ort och distansarbete, har varit begränsad till modelleringsövningar (e.g. Safirova et al. 2003; Eliasson and Mattsson 2000). Ramjerdi (1994) hävdar, baserat på en panelstudie med två vågor som genomfördes före och efter införandet av vägtullsystemet i Oslo i februari 1990, att vägtullarna inte hade någon kortsiktig effekt på bostads- eller arbetsort. Transaktionskostnaden för att byta bostads- eller arbetsort är mycket större än vägtullskostnaden. På lång sikt skulle ett hushåll kunna ta hänsyn till vägtullskostnader om ett byte av bostadsort är aktuellt av andra skäl (t.ex. på grund av livscykel, ändrad inkomst osv.). Ramjerdi visar även att systemets effekt på valet av resmål har varit statistiskt signifikant för orter med tjänster och företag belägna närmare vägtullsringen. Omfattningen av dessa effekter är emellertid ganska liten.

I kapitel 6 finner vi, genom en undersökning av boende i Trondheim, att vägtullarna spelade en relativt liten roll i de förväntade valen av bostadsort och arbetsort på medellång och lång sikt (ungefär 11% av respondenter) och nästan ingen roll i tidigare flyttningar (ungefär 2% av respondenter). Det här är föga förvånande, med tanke på den mängd övriga faktorer som tros påverka valet av ort. Å andra sidan uppger 18 % av de svarande i undersökningen i Trondheim att de valde distansarbete för att undvika vägtullarna, där dessa svaranden oproportionerligt var höginkomsttagare. Detta tyder på att det är värt att forska vidare på kopplingen mellan vägtullar och distansarbete.

2.3.3 Attityder till och acceptans för trängselavgifter

Vår forskning har givit ett betydelsefullt bidrag till det växande området kring acceptans för vägtullar, genom att tillhandahålla viktig empirisk evidens och genom att koppla attityder till rättviseprinciper. Exempelvis visar kapitel 3 det välbekanta mönstret där motståndet minskar efter genomförandet av avgiftssystemet i de flesta, men inte alla städer, fast oppositionen i Trondheim och Oslo fortsatt som en majoritet, även efter sådana minskningar. Dessutom var oppositionen före genomförandet i 2014 större än oppositionen före genomförandet i 2005, vilket tyder på att trots nedgången efter genomförandet kan upprepade vägtullsinitiativ ha en tröttande effekt på acceptans. Detta är kanske i linje med den vanligaste orsaken till motstånd enligt undersökningen: synen att tillräckligt mycket skatter och avgifter redan betalas.

Vi visar sedan i kapitel 7 att ökande acceptans av trängselavgifterna i Göteborg efter införandet bäst förklaras av så kallad *status quo bias*, där respondenterna har en naturlig tendens att föredra den aktuella situationen när frågan ställs. Attityderna kring rättvisa i allmänhet verkade emellertid inte påverkas av erfarenheten av trängselavgifter i Göteborg. Betänkligheter avseende social rättvisa var inte starkt kopplade till attityder till trängselavgifter.

Skillnaderna i attityder till trängselavgifter mellan de olika städerna verkar delvis kunna förklaras av vilken andel av befolkningen som betalar vägtullar: I Göteborg, t.ex., är det en större andel av invånarna som kör bil och faktiskt betalar vägtullar, och en större andel verkar där vara emot vägtullarna. Det här verkar vara nära kopplat till attraktionskraften hos alternativ till att betala vägtull. I Göteborg, jämfört med Stockholm, hade trängselavgifterna mindre effekt på antalet resor genom vägtullspassagen, räknat i procents minskning. Stabiliseringen tog även mycket längre tid i Göteborg. Resenärer med lägre inkomst i Göteborg och Stockholm betalar en högre andel av sin disponibla inkomst i trängselavgifter än resenärer med högre inkomst, även om resenärer med högre inkomst betalar mer i absoluta tal. Dessutom visade det sig att resenärer med högre inkomster i Stockholm i större utsträckning har tillgång till en tjänstebil, så att marginalkostnaden för resor genom vägtullspassagen normalt inte belastar personen, utan betalas av arbetsgivaren.

2.4 Politiska följder

De fynd som beskrivs ovan bekräftar en misstanke som länge har funnits bland förespråkare av vägtullar – nämligen att individer hittar en mängd olika sätt att anpassa sig till vägtullar, säkerligen utöver de sätt som de flesta forskare har möjlighet att mäta. I det här fallet var både distansarbete och omorganiserade reseturer associerade med vägtullar i olika fallstudiestäder. Något som är viktigt att poängtera är att tillgång till ett bredare urval av anpassningsmekanismer innebär en mindre anpassningsbörda eftersom individerna följaktligen har ett större antal sätt att optimera det näst bästa alternativet om vägtullen är för dyr. Även om denna studie har utökat antalet identifierade anpassningsmetoder, kvarstår emellertid många andra former av anpassning som är antingen dyra att mäta (t.ex. frekvens av vissa reseändamål över längre tidsperioder) eller nästan omöjliga att tillskriva vägtullar som orsak (t.ex. förändring av valet av resmål för resor som görs sällan). Den senare kategorin omfattar även förändringar av bostadsort, vilket framkom i Trondheimsundersökningen.

Samtidigt gav fynden relaterade till acceptans en stark indikation på betydelsen av *status quo bias*, med andra ord att motståndet mot en politisk åtgärd är mycket starkare innan den har genomförts än efter att den har genomförts. Det här kan tillskrivas den osäkerhet som är associerad med den föreslagna, men inte genomförda åtgärden, och kanske även en överdriven förväntan på åtgärdens effekter (både positiva och negativa), jämfört med de verkliga effekterna efter genomförandet. Det här kan även hänga samman med ovanstående fynd att människor har flera sätt att anpassa sig till en åtgärd än vad forskarna normalt förväntar sig. Följden är att den sammantagna effekten av förändringen är mindre än förväntat, och de här anpassningsstrategierna kan vara så subtila och diffusa på lång sikt att resenärerna glömmer att de har antagit dem, vilket gör att de tolererar det nya *status quo* bättre än de förväntade sig att de skulle. Denna forskning har även begränsningar när det gäller att fånga de sätt på vilka allmänheten och företag anpassar sig till ett vägtullsystem eftersom data vanligtvis är begränsade till partiella tvärsnittsdata.

Sammanfattningsvis kan det sägas att de politiska följderna är trefaldiga: 1) den genomsnittliga bördan av att anpassa sig till en vägtull är antagligen mindre än vad man först trodde, på grund av bredare anpassningsstrategier än de som beaktats vid tidigare analyser, 2) skillnaderna mellan befolkningsgrupper döljs ofta av sådana komplicerade anpassningsmekanismer, och 3) de här anpassningsmönstrens diffusa karaktär kan leda till att resenärer accepterar vägtullar efter införandet med mindre svårighet än vad tidigare indikationer kan antyda.

Det är lockande att tänka att dessa resultat tyder på att beslutsfattare helt enkelt kan tvinga fram ett nytt eller ändrat vägtullsystem, med vetskapen om att individer på något sätt kommer att hantera det och acceptera det, trots att de uppger att de är emot det. Då bortser man emellertid kanske från två viktiga samhällsprinciper, där det ena är korrekt offentligt samråd innan man genomför åtgärder och det andra upprätthållandet av ett rättvist samhälle även för personer som inte uttalar sina invändningar.

För att tjäna det första målet bör den offentliga sektorns tjänstemän sträva efter att inte bara presentera det föreslagna vägtullsystemets utformning i offentliga samrådssammanhang, utan även komplettera detta med realistiska analyser av de typer av anpassningar som har observerats på liknande avgiftssystem, med lämpliga anpassningar enligt den lokala omgivningen, så att individerna lättare kan föreställa sig vad det nya ”*status quo post*”, alltså efter införandet, kan innebära för dem själva. För att uppfylla det andra målet bör vägtullspolitikens detaljerade mekanik, när det gäller berörda typer av fordon, geografisk konfiguration och schema över avgiftsnivåer, analyseras med hänsyn till den lokala befolkningens geografiska och demografiska fördelning, så att skillnader i förmåga att anpassa sig, som de som vi har funnit i denna studie, kan förutses och användas för att eventuellt justera utformningen.

2.5 Framtida forskningsbehov

Ett antal forskningsbehov kan identifieras utifrån projektets sammantagna resultat. För det första är slutsatserna här begränsade särskilt där det gäller att identifiera anpassningsmekanismer, på grund av att resvaneundersökningarna i alla städer uteslutande är baserade på individer och inte hela hushåll, och på en dags resande och inte flera dagar i sträck. Den första begränsningen gör de omöjligt att dra slutsatser om hur hushållsmedlemmar omfördelar sina resor mellan familjemedlemmar, och den andra gör det svårt att skilja mellan vägavgiftsystemens effekter å ena sidan, och naturliga variationer i resande mellan dagar på den andra. Framtida studier skulle gynnas enormt av mer heltäckande resvaneundersökningar som tar hänsyn till både dessa aspekter.

För det andra finns det flera möjliga förklaringar till skillnaderna i anpassningar inför vägtullar i de olika städerna, t.ex. mellan Göteborg och Stockholm. Vi ställer upp fyra hypoteser som skulle kunna ha betydelse för framtida forskning:

- Människor ändrade sina resvanor i början och återgick sedan till gamla resvanor eftersom de inte hittade något lämpligt alternativ (t.ex. brist på bra kollektivtrafikalternativ). En undersökning skulle sannolikt kräva en panelstudie på flera dagar med intervall mellan vågor på 3–6 månader. I de flesta städer är en sådan undersökningsdesign dyr och något som sällan genomförs.
- Människor överskattade den negativa effekten av trängselavgifter och återgick när de insåg att den inte var så svår som befarat. Den här hypotesen skulle kunna kräva en undersökning med ännu kortare intervall, utförd under de första månaderna efter att en vägtull har införts eller ändrats, och undersökningen ska mäta ”förväntningar” på ett konsekvent sätt.
- Beteendet förändrades beroende på vilken signal trängselavgifterna förmedlade. Trängselavgifterna i Stockholm marknadsfördes som en miljöåtgärd. I Göteborg sågs trängselavgifterna som ett sätt att finansiera ett infrastrukturpaket. Miljömärkningen av trängselavgifterna i Stockholm skulle kunna fungera som en signal för ett socialt acceptabelt beteende. Faktum är att stora mängder pågående forskning, både i Skandinavien och på andra ställen, tittar närmare på miljöidentifieringens roll när det gäller att påverka beslut om resor.
- Resor över långa avstånd måste korsa vägtullssnittet i Göteborg, Trondheim och Oslo, medan de kan undvika avgifterna i Stockholm. Resor över långa avstånd är sannolikt mycket mindre känsliga för skatterna, vilket skulle kunna förklara en del av skillnaderna mellan effekterna i Stockholm och i de tre övriga städerna.

Data kring den allmänna acceptansen för ett vägtullsystem visar också olika resultat när man jämför Stockholm och Göteborg med Oslo och Trondheim. I Sverige verkar den allmänna acceptansen öka efter att ett system har införts, medan det här svenska fenomenet inte stöds av data i Norge. Skulle kulturella skillnader mellan Norge och Sverige kunna förklara skillnaderna? Sverige är känt för en högre grad av paternalism än Norge. Kan detta vara orsaken?

Vilka faktorer (t.ex. de upplevda effekterna av en åtgärd) skulle leda till ökad acceptans för en åtgärd, t.ex. ett vägtullsystem? Hur ändrar olika befolkningssegment (inte bara baserat på de observerade socioekonomiska variablerna, utan även baserat på deras attityder, vanor osv.) sin acceptans för/attityd till ett vägtullsystem? En förståelse för de här punkterna skulle kunna hjälpa planerare att lyckas bättre med att övertyga individer om att de bör anpassa sitt beteende till allmänhetens intresse. Användning av mer avancerade ekonometriska metoder, såsom latenta kategori- och latenta variabelmodeller för lämpliga data, är idag en möjlighet.

2.6 Rapportens uppbyggnad

Denna slutrapport består av en sammanställning av delrapporter för projektets enskilda arbetspaket. I varje delrapport identifierar vi en serie centrala forskningsfrågor och avslutar med fynden relaterade till samma frågor. Vi börjar med kapitel 3, som är taget från Arbetspaket 5 och ger en bakgrund till de fyra fallstäderna och gör ett antal jämförelser beträffande såväl deras utformning som deras övergripande effekter på trafiken. Därefter presenterar kapitel 4 de första resultaten från Arbetspaket 2 om individers anpassningsmönster i förhållande till vägtullarna i Göteborg. Därefter presenterar kapitel 5 de slutliga resultaten från Arbetspaket 2 där mekanismerna bakom anpassningsmönstren i Stockholm utforskas. I kapitel 6 lägger vi fram resultaten från Arbetspaket 3, som främst består av en undersökning av individers självrapporterade anpassningsmönster i Trondheim och hur dessa var relaterade till vägtullsringen. Slutligen använder kapitel 7 resultaten från Arbetspaket 4 för att analysera mönstren för acceptans för trängselavgifter särskilt i Göteborg och hur dessa är relaterade till frågor kring jämlikhetseffekter.

3 Overview of Four Scandinavian Toll Rings and their Experiences (Work Package 5)

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3.1 Background

Road user charging is a well-researched transportation policy, yet the experience of implemented congestion charging systems is scarce. Hence, the reported effectiveness of individual cases becomes more important for both researchers and policy makers. To be sure, it is not certain that effects identified in one city are directly transferable to another context. Comparing responses to congestion charges in Gothenburg, Stockholm, and to some extent also Trondheim and Oslo, thus provides an opportunity to assess how responses to congestion charges varies in different contexts. These cities differ in several dimensions such as size, initial road congestion, population density and availability of efficient public transport. Furthermore, the toll design and toll levels vary between these cities. Comparing responses in these cities thus provides the possibility to analyse whether the effects and adaptations are similar in different contexts, and, if not, describe the differences. A recent article (Börjesson, Brundell-Freij, and Eliasson 2014) suggests that the effects of congestion charges are fairly robust to changes in public transport supply and road capacity. This article is based on a transport model and it is interesting to complement this analysis with an analysis of empirically observed adaptation responses in cities that have implemented congestion charges.

The circumstances above lead to a set of research questions[3]. These research questions are particularly focusing on a comparison between the congestion charging schemes in Stockholm and Gothenburg, even though some comparisons also are made with Oslo and Trondheim:

- RQ 5.1: Will a smaller share of Gothenburg's drivers shift to public transport when they are "priced off" the road?
- RQ 5.2: If so, since the overall traffic reduction is about the same as in other cities such as Stockholm, which other responses were made instead?
- RQ 5.3: If there is a difference in this respect, is it more pronounced in some population segments than in others?
- RQ 5.4: Are the differences in adaptation responses between cities reflected in the consequences for individual travellers with respect to, for example, total travel time to work?

Above, the research questions are presented as they were formulated in the project proposal. During our research, we have gained a deeper understanding of contexts and relationships, and new insights to the limitations of the different data sources, which has redirected our interests somewhat and also led us to the conclusion that some of the questions cannot be (fully) "answered". Therefore, the research questions should rather be interpreted as representing the starting points, central aspects and focal areas of our research.

We return to a discussion of each research question in section 0

In order to compare responses in different cities it is important to describe the specific contexts in each city. A brief overview of each city´s characteristics (Section 3.2) and congestion charging system (Section 3.3) will be provided before the adaptation responses are analysed (Section 3.4). In the final section the results are summarized and discussed (Section 3.5).

3.2 Local Context

City characteristics can have considerable influence on the propensity to travel with different transport modes. For instance, the urban form and the public transport supply influence the attractiveness to travel with different transport modes. In this chapter we will briefly outline some key characteristics in the studied cities.

Stockholm

Stockholm is built on islands and thus has many water barriers. It has a population of around 0,9 million and the region has about 2 million inhabitants. The congestion charges are located around the inner city and about 330 000 people live within the congestion charging zone (see Figure 3.1). There are about 23 000 workplaces and 318 000 employees within the toll zone, of which about two thirds commute from outside the zone (Börjesson, Brundell-Freij, and Eliasson 2014).

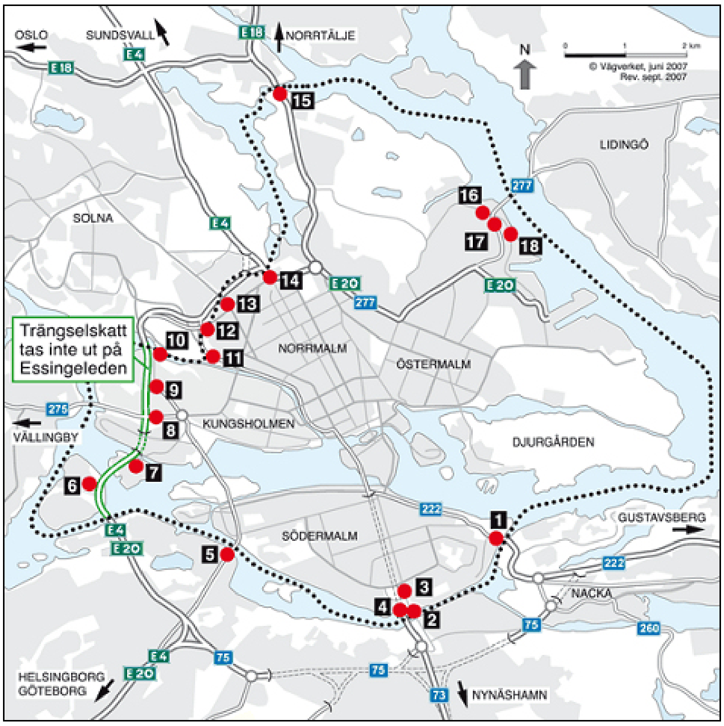

Figure 3.1 Checkpoints for Congestion charging in Stockholm.
(Original system. New stations have been added November 2014 and January 2016)

Stockholm has a well-developed public transport system comprising an underground system, commuter trains as well as busses. Public transport is the predominant transport mode for commuting across the cordon with a modal share of around 77%. Around 400 000 motor vehicles per day cross the cordon during congestion charging hours.

Gothenburg

Gothenburg is a sprawled city with a fairly low population density. The population in Gothenburg (municipality) is about 0,5 million people and there is about 1 million people living in the region.

Public transport supply is not as high as in Stockholm. Gothenburg has busses, tramways and regional trains from surrounding cities, but it does not have an underground system. Furthermore, the sprawled city structure makes it more difficult for public transport to be an efficient alternative to the car. Public transport has a modal share of 26% for commuting trips across the cordon (compared to 77% in Stockholm). Tolls are placed along a ring cordon as well as along two extended boundaries along the Göta Älv (see Figure 3.2). About 500 000 vehicles pass the tolls during congestion charging hours.

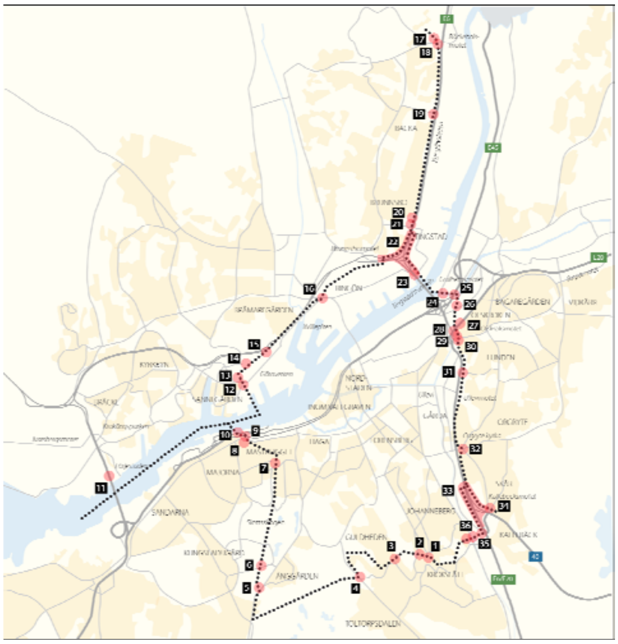

Figure 3.2 Checkpoints for the congestion charging system in Gothenburg

Oslo

Oslo implemented congestion charges in 1990, and we will therefore describe the characteristics of Oslo in 1990. The Oslo municipality had a population of about 480 000 and the region about 750 000 inhabitants in 1990. About 55 per cent of employments and 30 per cent of residences were located inside the toll ring.

The traffic enters the city along three corridors where toll stations are placed (see Figure 3.3), and about 208 000 motor vehicles crossed the toll ring on an average day in 1990. About 260 000 motor vehicles cross it during a working day.

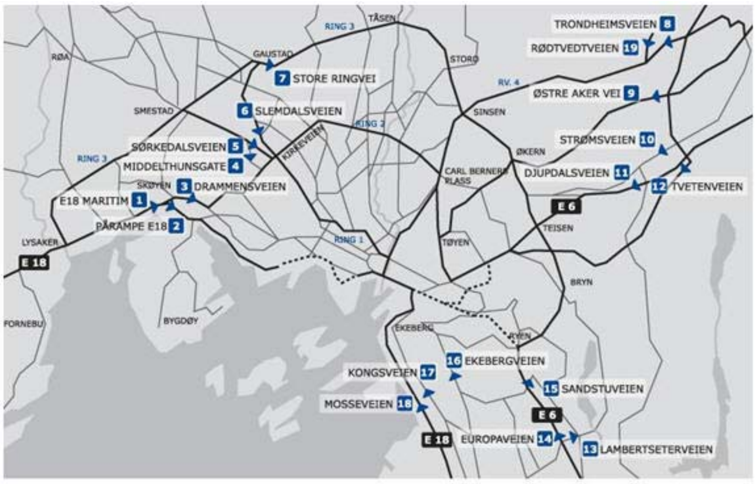

Figure 3.3 Crossing points along the Oslo toll ring

Trondheim

Trondheim is situated south of the river Nidelva in the Trondheim fjord. The city has mainly developed along two corridors. The congestion charging scheme was originally introduced in 1991 to finance a package of road and public transport projects. It was abandoned in 2005 and reintroduced in 2010. The scheme was significantly modified in March 2014 to a cordon toll as an environmental scheme. There are 22 toll stations in the new scheme introduced in 2014. These toll stations form a cordon around the city centre (see Figure 3.4). The population in Trondheim was about 182 000 in 2014. The total population, including students, was about 200 000 and the population of the greater Trondheim region is estimated at 250 000. About 245 000 vehicles passed the toll cordon on an average day before the introduction of the scheme in March 2014. This is expected to decrease by 15% to about 210 000 vehicles after the introduction of the tolls.

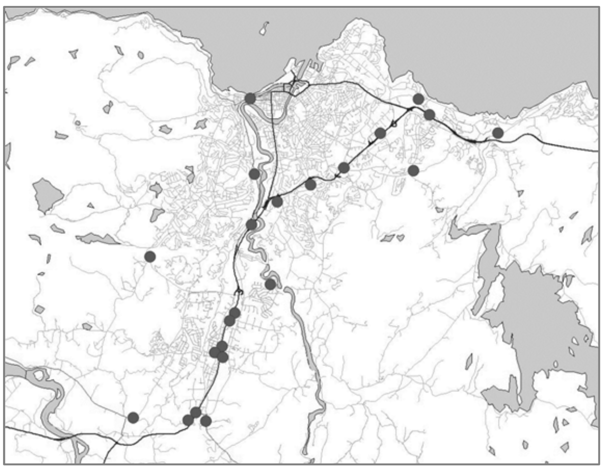

Figure 3.4 Checkpoints for congestion charging system in Trondheim

3.3 The Congestion Charging Schemes

The designs of the congestion charges vary between the four cities. One crucial difference, which has considerable impact on the effects, is the purpose of the congestion charges. In some cities (as Stockholm) the main purpose with the scheme was, at least discursively, to contribute to a better environment and reduced congestion, while the main purpose in Oslo was expressly to raise revenues. The schemes are thus designed with different priorities – in Stockholm the aim is to reduce traffic (and thus congestion and pollution), whilst in Oslo the objective was to reduce the flow of traffic as little as possible (and thus generate sufficient revenues). The four congestion charging schemes are briefly explained in the following section.

Stockholm

The original congestion charging system in Stockholm[4] is a time-varying toll system from Monday to Friday. The charges are 20 SEK (about € 2) during peak hours (7.30 – 8.30, 16.00 – 17.30), 15 SEK for the 30 minutes before and after peak hours and 10 SEK at other times (between 6.30 and 18.30). The maximum charge per day is 60 SEK. Some vehicles are exempted from the toll: motorcycles, busses and vehicles with a disability permit. Most measurements of the effects originate from the trial period in 2006, when also environmentally certified vehicles and taxis were exempt. Furthermore, vehicles from Lidingö (an island), that passes through the entire zone (i.e. vehicles that entered and exited the zone within 30 minutes), are exempted from the toll.

A congestion charging trial was first implemented in 2006, before the toll was implemented on a permanent basis. A referendum was subsequently held (September 2006) in the City of Stockholm and a few surrounding municipalities before the permanent implementation of the tolls. To the voters in Stockholm, the referendum question was conditioned on the revenues from the tolls being used for investments in road and public transport infrastructure. Until now, the revenues have been earmarked for road infrastructure, but from January 2016 higher charges will be implemented, with the increase being linked to investments in new subway lines (Stockholmsförhandlingen 2013).

Gothenburg

The congestion charging system in Gothenburg is a time-varying toll system, similar to that in Stockholm. The charges varied between 8, 13 and 18 SEK depending on the time of the day. The charges apply from 6 am to 6.30 pm Monday to Friday[5]. The maximum charge per day is 60 SEK. As in Stockholm, some vehicles are exempted from the toll: motorcycles, taxis, busses and vehicles with a disability permit.

The introduction of congestion charges was tightly linked to the planning of a large infrastructure package (*Västsvenska paketet*) with both rail and road investments for which the revenues are earmarked. The system is however designed to also reduce congestion and environmental pressure from traffic.

[4] Note that the charges were increased on the first of January 2016. The new charges vary between 11, 15, 25 and 35 SEK depending on the time of the day. Furthermore, the system was extended to also comprise new checkpoints on Essingeleden, where the charges vary between 11, 15, 22 and 30 SEK depending on the time of the day. The data analysed in this report refer to the original system.

[5] These were the charges during the evaluation of the congestion charging scheme. These charges have been increased to 9, 16 and 22 SEK per passage since the 1st of January 2015.

Oslo

The two Norwegian schemes are different to the Swedish ones in that tolls apply around the clock, seven days a week. The purpose with the tolls in Oslo was expressly to raise revenues, mainly for road investment (Oslo package 1, 2 and 3). The system is thus designed not to discourage paying vehicles to a great extent, and not to reduce traffic (as the Stockholm case). At the introduction in 1990 the charge was fixed at 10 NOK per passage, but it was also possible to buy a monthly pass (220 NOK), a 6-month pass (1200 NOK) or a yearly pass (2200 NOK) This is a big difference from the toll design in Stockholm and Gothenburg, where one must always pay for each passage up to a daily maximum fee of 60 SEK. This tariff structure implies that, once a pass is purchased, there is no marginal cost for passing the cordon. A majority of all passages were made by vehicles holding seasonal passes in 1990 (about 9 months after the introduction of the toll scheme), about 35% of household reported that they had cars with seasonal pass in their household, and in 1991 63% of the crossings over the cordon toll were made by cars that had a subscription.

Trondheim

In Trondheim, like in Oslo, tolls apply around the clock, seven days a week. The charges do however vary with time and doubles during the peak periods (07-09 and 15-17) Mondays to Fridays. The fee is 10 NOK at non-peak hours and 20 NOK at peak. Only the first crossing is charged if several toll stations are crossed at during the same trip. The maximum charge is for 110 passages per month.

The congestion charges were re-implemented in Trondheim in 2014 and the effects of that system for congestion charges are thus not yet available. The revenues from the new congestion charges are linked to a transport investments package, mainly constituted by road and public transport investments.

3.4 Responses to Congestion Charges

When starting this project we had the expectations to analyse different adaptation responses more thoroughly with the Gothenburg sample, and compare those to corresponding findings from Stockholm, Oslo and the (original) Trondheim ("old system"). However, it turned out more difficult than expected to separate different adaptation responses, and to quantify their relative contribution to the reduction of car volumes. These difficulties arouse despite that the Gothenburg sample was more efficiently designed, and both waves were conducted in the same month (thus avoiding the large problem with seasonal variation that is inherent in the Stockholm data). Part of the difficulty is due to "the fact that discretionary travel patterns are not 'stable'—the adaptation possibilities are much more multi-faceted, and trips are not 'replaced' on a simple one-to-one basis" (Franklin et al. (2009) .

In this chapter we will discuss responses to congestion charges, and where it is possible, also reflect upon different adaptation responses, with a focus on comparisons between cities. For a deeper analysis of Gothenburg data, involving also analysis of trip chaining behaviour, we refer to Chapter 4.

The traffic reduction varies considerable between the three studied cities in this comparison (no evaluations are yet available for Trondheim). We will first give a brief overview of the aggregate results and then discuss how the adaptation to congestion charges varies between different demographic segments in Gothenburg and Stockholm. This chapter focuses on Stockholm and Gothenburg, but some general remarks will also be made about Oslo.

3.4.1 The Traffic Reduction in Stockholm, Gothenburg and Oslo

The total traffic reduction due to the congestion charges varied between the studied cities (see Table 3.1). We discuss the traffic effects for each city in turn.

Table 3.1 Traffic reduction over toll cordon (in % of all traffic)[6]

City	Oslo	Trondheim	Stockholm	Gothenburg
Charge per passage	10 NOK (1990) (1.1€)	20 NOK (2.2€)	10 – 15 – 20 SEK (2.2€ at peak) Increased from Jan 2016	8 – 13 – 18 SEK (1.9€ at peak) (9 – 16 – 22 SEK from2015)
Initial reduction	3-5%	15% (*prediction*)	24%	20%
% Per EUR at peak	3,64%	6,82%	10,00%	6,32%
Long term reduction	-	-	22%	12%
Time to stabilize	-	-	2 months	10 months

Stockholm

The number of vehicles passing the cordon during charging hours did decrease by 22% in Stockholm when the charges were introduced. The effect was slightly higher during the first month (-24%), but it stabilized at -22% after 2 month. This effect has remained constant since the first implementation of the congestion charging scheme (in 2006). The traffic reduction has remained constant since 2006, despite population increase. Today, traffic volumes across the cordon are smaller than what would be expected, when population growth, fuel price increases and economic development are taken into account. This has been interpreted as the long term effect of the congestion charges are being larger than the corresponding short term effect (Börjesson et al. 2012). (There may of course be other contributing factors as well.)

The congestion charges were first introduced for seven months at a trial basis in Stockholm. After the trial followed a period without congestion charges before the charged were permanently reintroduced in 2007. An interesting observation is that about 1/3 of the traffic reduction remained during the period that the congestion charges were removed.

The largest reductions on congestion were observed on arterials to the inner city, which also were the most congested areas prior to the toll. The time in congestion (i.e. excess travel time compared to free flow) was on average reduced by about 50% on morning and afternoon peaks on these roads. In the inner city, the same congestion indicator was reduced by about 20%. The congestion charges did thus reduce congestion significantly, although substantial congestion remains.

Gothenburg

The effect on vehicles crossing the cordon during charging hours was lower in Gothenburg compared to Stockholm. The initial reduction was about 20% in Gothenburg, but the traffic gradually increased again, and after 10 months the traffic reduction across the cordon was 11%.

[6] Sources: Statens vegvesen Region mid (2012); Ramjerdi, F. (1994); Trafikverket et al (2013b); Trafikverket et al (2013a), Börjesson et al (2012).

Before the introduction of tolls, congestion was not as wide-spread in Gothenburg as in Stockholm, but mainly concentrated to a few links close to *Tingstadstunneln*—the motorway tunnel under the river that runs through Gothenburg. On these congested links, the congestion was reduced by about 50% during the morning rush hour (7-8 a.m.) when charges were introduced. There are no available travel time data on the afternoon peaks for Gothenburg.

Oslo
We have less detailed information on the traffic reduction effects in Oslo. The toll was implemented in 1990 and the traffic reduction over the cordon was less than 3-5%.

Commuters did hardly change their travel behaviour due to the congestion charges in Oslo. Most of the adaptation (if not all) were for other trip purposes than commuting. Furthermore, people did not adapt to congestion charges by shifting transport modes in Oslo, but in other ways (e.g. not travelling, changing destination).

The introduction of tolls in Oslo thus had a much smaller, and quite different, effect compared to what was later seen in Stockholm and Gothenburg. It is likely that the availability of cheap seasonal passes (see Section 3.3 above) in Oslo played a major role for those differences.

Trondheim
In our review of available data sources, we have been unable to obtain traffic data of a sufficiently similar character to the data from the above cities, to be able to make comparisons.

3.4.2 Modal shift
For Gothenburg, we analyse adaptation patterns based on a two-wave panel study. The final sample (completing both waves) was 2 924 respondents who live in Gothenburg or the surrounding municipalities.

Different adaptation mechanisms (for example modified trip chaining patterns – see Chapter 4) will affect the number of trips and their distribution over modes, OD relations etc., in a complex way involving also relations that are not directly affected by the introduction of charges. In the analysis in Table 3.2 it has therefore not been possible to control for the effect of potential contributing factors other than charging. The analysis leads to the conclusion that 33% of the total "effect" – reduced number of cars over the cordon – could be attributable to a change in modal split.

Table 3.2 Mode choice effects in Gothenburg; sources: Trafikverket et al (2013b), Trafikverket et al (2013a)

Number of trips	**Before**	**After**	**Effect (after - before)**
…across cordon	533 177	503 089	-30 088
…across cordon by car	373 464	342 377	-31 087
…across cordon as a car driver (no of cars)	252 141	230 293	**-21 849**
Car mode share across cordon	70%	68%	
The observed modal shift corresponds to a (hypothetical) reduction in no. of cars across cordon	252 141	244 977	**-7 164**
			33%

In the official report from the travel survey (Göteborgs stad 2013) the analysis of the same raw data is based on a somewhat different approach, and different assumptions. The overall conclusions are never the less rather similar as those in Table 3.2, even if a slightly higher proportion (50%) of the disappearing car trips were reported to have been replaced by public transport trips in the official evaluation.

In the Stockholm case, the analyses of adaptation patterns were even more complicated, since mode choice effects are confounded with seasonal variation in the travel survey data. Despite these difficulties, Franklin et al (2009) make an attempt to describe the adaptation pattern – including modal shift - based on reasonable assumptions (but without consideration to potential trip chaining effects). Their conclusion was that of the total reduction of private car trips across the cordon, modal shift accounts for 60 percent.

When congestion charging was introduced in Oslo, the official evaluation (Ramjerdi 1994) concluded that there were no indications that modal shift effects contributed to the reduction of car travel across the cordon.

3.4.3 Proportion of Household Income allocated to Congestion Charges in Gothenburg

We have made an indicative analysis of how the burden of the imposed toll is distributed over different income segments, shown in Table 3.3. The population is divided into three groups according to their income per consumption unit[7], and the toll paid was estimated from travel survey data. The analyses indicate that people in low income households pay on average about 1300 SEK per year in congestion charges. The equivalent for people in high income households is 2400 SEK per year. However, although people in low income segments spend less in absolute terms, our result indicate that they spend a larger *proportion* of their disposable income on congestion charges than people in high income households (0,7% of household income in low income households compared to 0,4% of household income in high income households).

Table 3.3 Proportion of household income allocated to congestion charges in Gothenburg[8] (over all individuals, irrespective of car ownership and use), source: own analysis using Travel Panel in Gothenburg, 2013

Income quantile, (kSEK /year)	**Avg. income/ cons. unit**	**Est. avg. charge/ day (SEK)**	**Est. avg. charge/ year**	**Charge (pro-portion)**	**# Obs.**	**Car mode share**	**% of all trips across cordon**	**% of car trips affected by toll**	**Avg. charged car trips/ day**
Lowest Third (< 250)	173 000	5,7	1289	0,7%	499	47%	42%	18%	0,4
Middle Third (250-410)	332 000	7,4	1668	0,5%	800	53%	47%	23%	0,6
Highest Third (> 410)	656 000	10,6	2394	0,4%	836	64%	48%	30%	0,8

[7] Household income is divided by consumption units (c.u.), to better reflect the average disposable income of household members. First adult = 1 c.u.; each additional adult = 0,5 c.u.; each child = 0,3 c.u. To illustrate, for a family with 2 adults and 2 children, household income is divided by 2,1 c.u. Factors 0,5 and 0,3 are suggested by Eurostat and applied by OECD. Slightly different factors are used by Statistics Sweden.
[8] The analysis concerns the entire population, including those who have not travelled by car.

A similar analysis in Stockholm shows similar results (Eliasson 2014). The analysis in Stockholm also takes into account that people in high income households have access to company cars to a larger extent than low income households. Since company cars users do not pay the congestion charges themselves the Stockholm analysis actually shows that people from the highest income segment may actually pay less in charges than people with low income, also in absolute terms. Unfortunately, the Gothenburg data does not provide information on whether household cars are privately owned or company cars, but it is not unlikely that the same is true in Gothenburg.

3.4.4 Changes in Travel Time for Commuting in Gothenburg

In order to better understand the sacrifices that people in different income segments make when they adapt to the toll ("adaptation cost"), we have analysed how much the total reported commuting time changes for different income groups that:

- Commuted by car before the toll and continue commuting with car
- Commuted by car before but changed to public transport
- Commuted with public transport and continued commuting with public transport

The analysis is based only on individuals for which home and work locations remained constant (zone level) between the before and after studies. The analysis shows, in line with expectations, that car commuters that continue travelling by car save time (1,5 – 3 minutes one way) when the charges are introduced, and that car commuters who switch to public transport do so at the expense of a longer commute (increase by 17 – 19 minutes one way) (see Table 3.4). The differences between income groups are relatively small, but indicate that higher income groups may tend to have home/work locations that offer less competitive public transport alternatives.

Table 3.4 Changes in travel time for commuters, one way trip; source: own analysis using Travel Panel in Gothenburg, 2013

	Changed travel time (min)	
Income quantile	**Car to car**	**Car to PT**
Lower third	-2,3	17,0
Middle third	-1,4	17,1
Upper third	-2,9	18,8

3.5 Attitudes toward Cordon Tolls

In this section we summarize and compare the trends in attitudes toward cordon tolls in the four study cities. We start with additional focus on Oslo, which is otherwise not addressed in detail in the later chapters, and we follow with a short summary for Stockholm, Gothenburg, and Trondheim, as elaborated in later chapters.

3.5.1 Oslo

The history of the Oslo toll scheme can be summarised as follows:

- The scheme started operation in February 1990. The toll was set at 10 NOK. There were originally 17 toll stations, and this was extended to 19. Inbound traffic was tolled all day round, every day of the year (Oslo Package 1).
- In 2000 the Parliament approved "Oslo Package 2" with an increase in toll fee to 15 NOK. The proceeds were to be allocated to public transport purposes.
- In 2008 Oslo Package 3 was approved to finance road and public transport infrastructure and operation costs for the period of 2008-2027. The toll increased to 25 NOK and the toll ring was extended with new stations in the border between Oslo and Bærum in the west.
- The toll increased to 27 NOK in 2012.
- The toll increased to 31 NOK in 2014.

Figure 3.5 shows the public acceptance of the toll scheme in Oslo since 1989, before the scheme started operation until 2014. The initial public acceptance of the scheme, before it started operation, was similar to that in Trondheim: about 70% of the public were opposed to the scheme. The opposition declined to 64% after the scheme started operation in 1990 and gradually declined to 52% in 1998, as earlier documented (James Odeck and Bråthen 1997; James Odeck and Bråthen 1998). However, opposition increased again to 64% in 2001, coinciding with the debate and introduction of Oslo package 2.

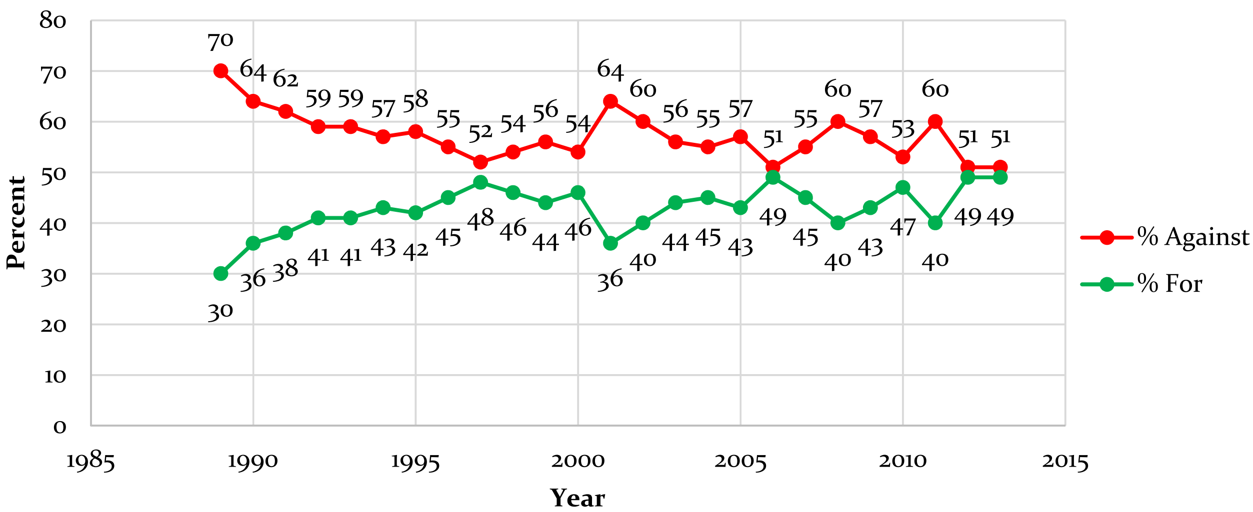

Figure 3.5 Historical support levels of the Oslo schemes; source: merged data from own analysis using public attitude survey of 1989-2014, constructed by the Norwegian Public Roads Administration for 1989 to 2009

The same pattern of public opinion swing emerged between 2001 and 2008, coinciding with the introduction of Oslo package 3.2 and Oslo package 3, as well as increase in toll fees. Again, opposition to the scheme increased with the discussion on increase in toll in 2011. The pattern of the swings of public opinion can be attributed to cognitive dissonance that boils down to “accepting the inevitable”. Public opposition to the schemes subsides over time, yet as soon as there is a new discussion of a change in the system it reignites public opposition to the schemes. As yet attitudes for have never been greater than against.

3.5.2 Stockholm, Gothenburg, and Trondheim

Attitudes in the Stockholm case are also not addressed in detail in this study, but as seen in earlier literature (Börjesson et al. 2012), support declined with the onset of discussions about congestion charging, then increased again after implementation (see Figure 3.6). In contrast to Oslo, the fee levels were never changed until January 2016, and at time of printing this report, no data is yet available on attitudes toward the tolls associated with this recent increase.

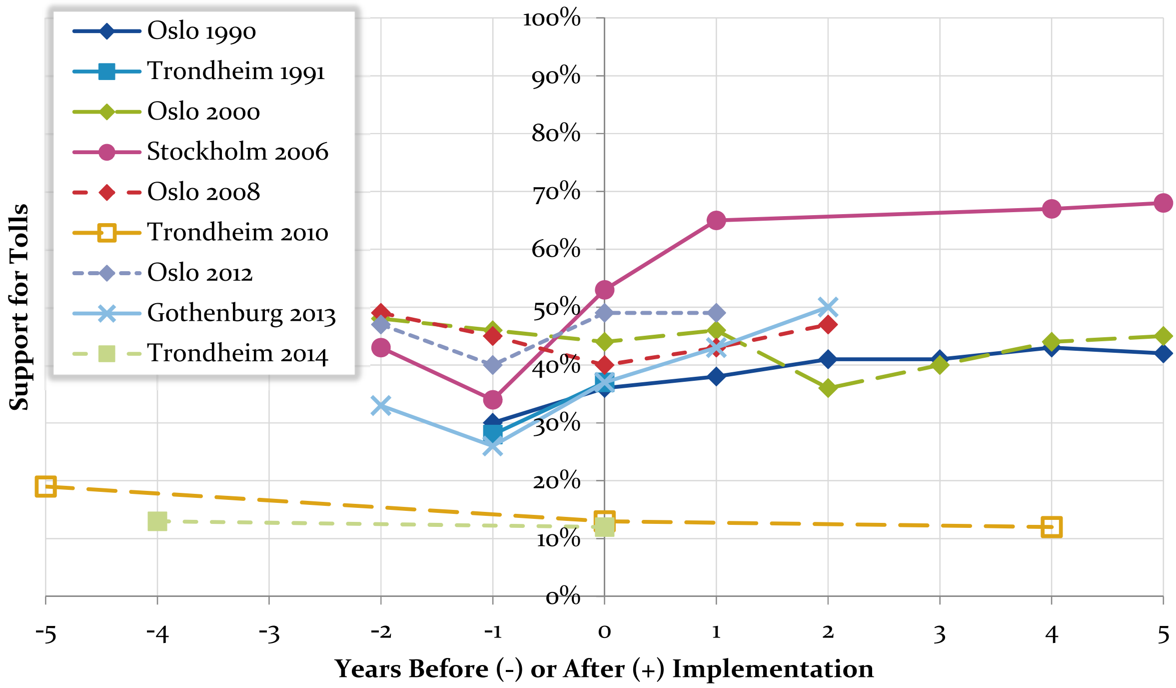

Figure 3.6 Support Levels for Cordon Tolls over Time[9]

Attitudes in Gothenburg and Trondheim are also shown in Figure 3.6. The results for the three Trondheim implementations are discussed in more detail in Chapter 6. For Gothenburg's congestion charging in 2013, the attitude survey results have been previously published (Börjesson and Kristoffersson 2015), and these findings are discussed further in Chapter 7.

What we can see from Figure 3.6 is a similar trend in many of the cases, with declining support prior to introduction, and increasing support after introduction. This trend is further discussed in the specific case studies, but it is interesting to note that it occurs frequently. However, another trend we see in the Norwegian cases with multiple implementations in the same city is that later implementations draw lower support than earlier implementations, suggesting that the population perhaps fatigues of cordon toll initiatives. Again, this is further discussed especially in the context of Trondheim.

[9] Sources: Public Attitude Survey (1989-2014), constructed by the Norwegian Public Roads Administration (1989 to 2009), Trondheim Public Opinion Survey (2014), Hamilton et al (2014), Börjesson et al (2012).

3.6 Review of Research Questions

As we have seen in this chapter, the congestion charging schemes in Stockholm and Gothenburg are quite similar in their design. However, these cities have quite different characteristics. Stockholm has very high usage of public transport for commuting over the cordon, and Gothenburg have more moderate public transport usage. Despite this, people make quite similar adaptation responses in these cities. In this section we will summarize some of the principal observation from the study.

RQ 5.1 Will a smaller share of Gothenburg drivers shift to public transport when they are "priced off" of the road?

Traffic reductions over the cordon are twice as high in Stockholm as in Gothenburg. The traffic reduction over the cordon is about 22% in Stockholm and about 12% in Gothenburg. What is interesting to note is that the effect stabilized rapidly in Stockholm (from an initial reduction of 24% to 22% in two months), while the stabilization took much longer time in Gothenburg (an initial effect of 20% gradually decreased to about 12%, ten months later). There are several possible explanations for these differences, and we will state four hypotheses:

- People changed in the beginning and then switched back as they did not find a suitable alternative (e.g. lack of good public transport alternative).
- People overestimated the negative effect of congestion charges and switched back when they realized that it was not as bad as expected
- The signal of the congestion charges affected behaviour. The congestion charges in Stockholm were promoted as an environmental measure. In Gothenburg the congestion charges were seen as a way to finance an infrastructure package. The environmental label of the congestion charging in Stockholm might work as a signal for a socially acceptable behaviour.
- That long distance trips have to cross the cordon in Gothenburg, whilst they can avoid the charges in Stockholm. Long distance trips are probably much less sensitive to the taxes, which could explain a part of the differences in effects between Stockholm and Gothenburg.

Focusing modal shift specifically, our analyses indicate that it played a smaller role in Gothenburg (33% - as shown in Figure 3.2) than what has been reported from Stockholm (60%). This is according to expectations, since public transport offer less competitive alternatives in Gothenburg. In Oslo, it was reported that modal shift did not contribute at all.

RQ 5.2 If so, since the overall traffic reduction is about the same as in other cities such as Stockholm, which other responses do they make instead?

The research question was formulated before the long term rebound effect in Gothenburg had been identified in measurements. In the end the overall reduction of car volumes in Gothenburg was only half of those in Stockholm (-11% compared to -22%). Therefore, the fact that there was less modal shift occurring in Gothenburg, is not necessarily compensated by any "other" adaptation responses being made "instead". We have however identified (see Chapter 4) that people in Gothenburg tend to adapt through more efficiently arranged trip chains. No such effect is distinguishable in Stockholm.

RQ 5.3 If there is a difference in this respect, is it more pronounced in some population segments than in others?

Low income groups pay a higher proportion of their disposable income in congestion charges. High income households pay more in congestion charges than low income groups, but low income households pay a higher proportion of their disposable income. This is the case both in Stockholm and

Gothenburg. The proportion of the household income spent on congestion charges are on average low (0,4-0,7%). An analysis in Stockholm (Eliasson 2014) indicates that high income households, on average, may pay less in congestion charges than low income households even in absolute terms, as they have access to company to a larger extent. No such analysis has been in Gothenburg, but it is not unreasonable to believe that the same pattern apply in Gothenburg.

RQ 5.4 Are the differences in adaptation responses between cities reflected in the consequences for individual travellers with respect to, for example, total travel time to work?

Car commuters switching to public transport lose 17-19 minutes in Gothenburg for their one-way trip. Car commuters that continue commuting by car gain after the introduction of congestion charges, 1,5-3 minutes each way.

4 Adaptation Patterns in Gothenburg (Work Package 2, Part A)

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In work package 2 we partially use new data from the Gothenburg implementation, which has several design advantages over earlier datasets, and partially apply new approaches to analysing the Stockholm data that have not previously been used.

Even when using similar methods and analysis as used in Stockholm, the Gothenburg panel survey is better suited for studying adaptation responses than the corresponding Stockholm panel data, hence the potential for drawing conclusions is far stronger. This is firstly because in the Stockholm data, the responses to the charges were confounded by large seasonal effects, due to the trial's start being postponed from September 2005 to January 2006. Moreover, in the Gothenburg panel data the sampling of the respondents is specifically designed to meet the needs of analyses on adaptation responses to congestion charges, which was not the case in the Stockholm survey: the sampling of respondents in the Gothenburg data concentrates on individuals who work and live on different sides of the cordon, whereas in the Stockholm panel these individuals made up only a very small proportion of the respondents.

Having analysed the Gothenburg data similarly to the earlier Stockholm studies, we then proceed to investigate more deeply the organisation of trips in households in the Gothenburg dataset. A particular type of adaptation mechanism that has not been studied in detail for Stockholm is trip chaining; past work has focused on "unlinked trips" of various kinds, taken in isolation. We look specifically into how the introduction of congestion charging affects trip chaining patterns. The methodological approaches that are typically applied to travel diary data deal with single trips as the basic object of analysis. Therefore, our specific interest in trip chaining will require recoding the travel diary data so that tours can be analysed and compared, at the level of both the individual and the household, and developing new analytical frameworks to analyse these data.

4.1 Data

The data for this analysis consisted of the Gothenburg panel travel survey, conducted in 2012 and 2013 (Göteborgs stad 2013). Residents aged 18-70 were recruited in an area consisting of Gothenburg Municipality, along with ten surrounding municipalities with significant shares of commuting patterns into Gothenburg, with a total population of around 607,000. The sampling was stratified according to two principles: 1) sufficient representation across different geographic areas, and 2) oversampling of respondents in areas that tend to travel across the planned toll cordon. Respondents were asked to report their travel movements on two study days, one day each in 2012 (before the tolls started) and 2013 (after the tolls started), where both days were sometime in the period of March to April. The response rate was about 1/3 (among the high end of normal response rates for such surveys), with over 3000 people responding, making a total of 17 000 trips over both study days.

4.2 Approach

The analysis involves quantitative comparisons in a series of travel behaviours across different groupings of the sampled population in Gothenburg. The behaviours we focus on are intended to capture, to some extent, the kinds of travel responses that are made in order to adapt to the twin effects of increased monetary costs and reduced travel times, for auto trips over the toll cordon during charging periods.

Based on the availability of relevant questions from the Gothenburg panel travel survey, we identified a series of indicators for travel choices before and after the congestion tax implementation:

- Car Mode Share (%) for All Trips, taken as the share of all Trip Segments between activities that are taken by car, either as a driver or a passenger.
- Average Automobile Occupancy for Respondents' Trips by Auto, taken as the Total Number of Car Trip Segments / Number of Car Trip Segments as Driver.
- Average Departure Time for Trips to Work/School, taken as the departure time for the first Trip Segment from Home on a Tour that leads to Work or School, even if there is an intermediate stop between Home and Work/School. Hence, any secondary Tours to Work are disregarded (e.g. after lunch at Home).
- Average Departure Time for Trips to Home after a Work/School Destination, taken as the departure time of the first Trip Segment from Work or School that leads to Home, even if there is an intermediate stop between Work/School and Home. Hence, Sub-tours from Work that do not lead Home are disregarded.
- Average Number of Trip Segments per Tour, where a Trip Segment is a component of a Tour that leads from one activity to the subsequent activity.
- Number of Tours per Day, where a Tour is a complete circuit from Home to at least one other activity, and back to Home again (i.e. Home-based). Sub-tours (e.g. complete circuits from Work back to Work again) are not counted separately from their corresponding Home-based Tours.

The first four statistics above help to identify how shifts from tolled auto trips translate to other kinds of behaviours, and specifically non-auto trips, increased automobile occupancy, and shifts in time of day. The remaining three statistics, on the other hand, help to characterise how the remaining auto trips are organised into tours, compared to before tolls were implemented. For each statistic, we computed an average across both "affected" trips and "unaffected" trips, where we define "affected" trips as those whose origin and destination are on opposite sides of the congestion charging cordon. We can thus treat the "unaffected" trips as a control group, while the "affected" trips are a treatment group whereby we take the introduction of the congestion tax cordon across the trip's path as the "treatment".

Following this formulation of indicators, we can assess the propensity for different individuals to exhibit different kinds of responses to the congestion tax. First of these is mode choice: by measuring the percent of total cordon-crossing trips that are made by car, and comparing this to the percent of non-cordon-crossing trips made by car, we can assess whether mode choice for those affected trips was more clearly affected. Similarly, by measuring car occupancy for both affected and unaffected trips, we can assess whether a greater share of car trips were with multiple travellers when crossing the toll cordon, compared to trips not crossing the cordon.

For departure time behaviour, we compute the average reported departure time for two specific types of trips: first, trips to the workplace or to school; and second, trips to the home that conclude a tour to work or school. This filtering helps isolate commute trips, which we know are predominantly focused to the peak demand hours of the day. By comparing departure times in 2012 and 2013 in reference to the time-schedule of congestion tax levels, which range from 8 SEK to 18 SEK when the tax is active, we can assess whether departure times appeared to be affected more on trips that crossed the cordon, compared to those that did not. Because of the nature of the charging schedule, these departure time changes could involve either earlier or later departures, depending on what type of reaction is observed.

Finally, for trip chaining behaviour, we start by identifying specific patterns of tour reorganisation that we hypothesise as responses to the congestion charges:

5. Consolidation of multiple tours into one multi-stop tour
6. Conversion of a home-based tour to a work-based sub-tour
7. Reordering of stops on a tour to minimize cordon crossings

We can summarize these behaviours with a series of indicators, as shown in Table 4.1. By tracking these indicators and comparing to the expected changes listed in the table, we can assess the extent to which "affected" tours were reorganised in response to the congestion tax.

Table 4.1 Typical Tour-Reorganising Behaviours and Associated Indicators

Tour-Reorganising Behaviour	**Indicator and Expected Change**		
	Total # Tours	**Total # Trip Segments**	**# Affected Trip Segments per Tour**
1. Consolidation of multiple tours	Reduced	Reduced	Reduced
2. Conversion of home-based tours to sub-tours	Reduced	Same	Reduced
3. Reordering of stops	Same	Same	Reduced

To emphasize demographic aspects in our results, we have focused on four different types of groupings:

- Gender: male or female
- Income per consumption unit: three 33% quantile groups (< 250 kSEK/year, 250—410 kSEK/year, and > 410 kSEK/year)
- Age in four categories: 18-25, 26-45, 46-65, and 66+
- Children in the household: No Children, Small Children (0-12), Youth (13-17), or Both

These groupings are far from comprehensive, but they build naturally on the available data from the travel survey, and they reflect the dimensions of demographics that tend to receive the greatest focus in literature.

4.3 Results

4.3.1 Mode Choice

Starting with mode choice, we computed the changes in average mode share for car for all trips, both for the entire sample and for each category of sub-population; the results are shown in Figure 4.1. As a basis for comparison, overall the car mode shares in 2012 were 58% for trips across the cordon, and 57% for other trips. In general, there is a clear reduction in car mode share for “affected” trips by over 7 percentage points, in contrast to a slight increase in car mode share for “unaffected” trips.

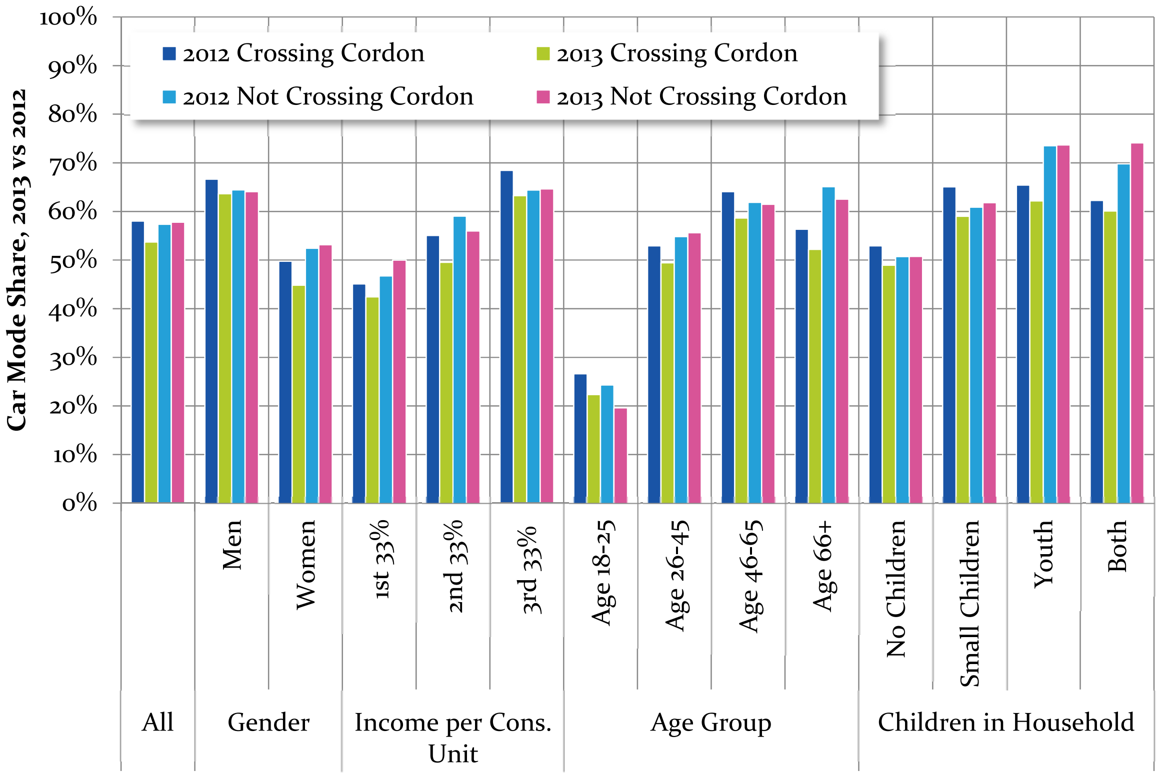

Figure 4.1 Average Car Mode Share in Gothenburg;
source: own calculations, using Travel Panel in Gothenburg, 2013

For the various population groups, we can first see that for “affected” trips, the reduction in car mode share for women is twice the reduction for men. We can also see that for “unaffected” trips, the opposite response is stronger for women than for men. This could indicate that women, to a larger extent than men, change destinations from “affected” locations to “unaffected” locations, and continue to drive a car for those trips[10]. Among the income quantiles, the middle quantile showed the strongest reduction, with the upper quantile second. It should be noted that the starting mode shares were least for the lower quantile and greatest for the upper quantile.

[10] Note that we have not included any direct indicators of destination choice in this study. This is a consequence of the intrinsic difficulty in matching trips between two different survey waves, when only one day is included in each wave. However, shifts between “affected” and “unaffected” trips can be seen as a weak indicator of altered destination choice.

The four age groups all exhibited reductions in car mode share, although the greatest reduction was among those aged 46-65. This is perhaps to be expected, since that group started with the highest car mode share of these groups. Finally, all family types showed reductions, where those with only small children in the household reduced the most.

4.3.2 Auto Occupancy

The second adaptation type is car occupancy, shown in Figure 4.2. These changes in auto occupancy should be compared to 2012 figures of 1.10 persons per car for trips across the cordon, and 1.12 persons per car for other trips. We would expect to see an increase in car occupancy associated with "affected" trips, as families try to combine their cordon-crossing errands into fewer vehicles, thus paying less per household. Indeed, overall "affected" trips saw an increase in average car occupancy but only of about 0.015, while "unaffected" trips saw an even smaller. This could lead to a reduction of 3 390 trips based on Table 3.2, equivalent to 16% of total reductions.

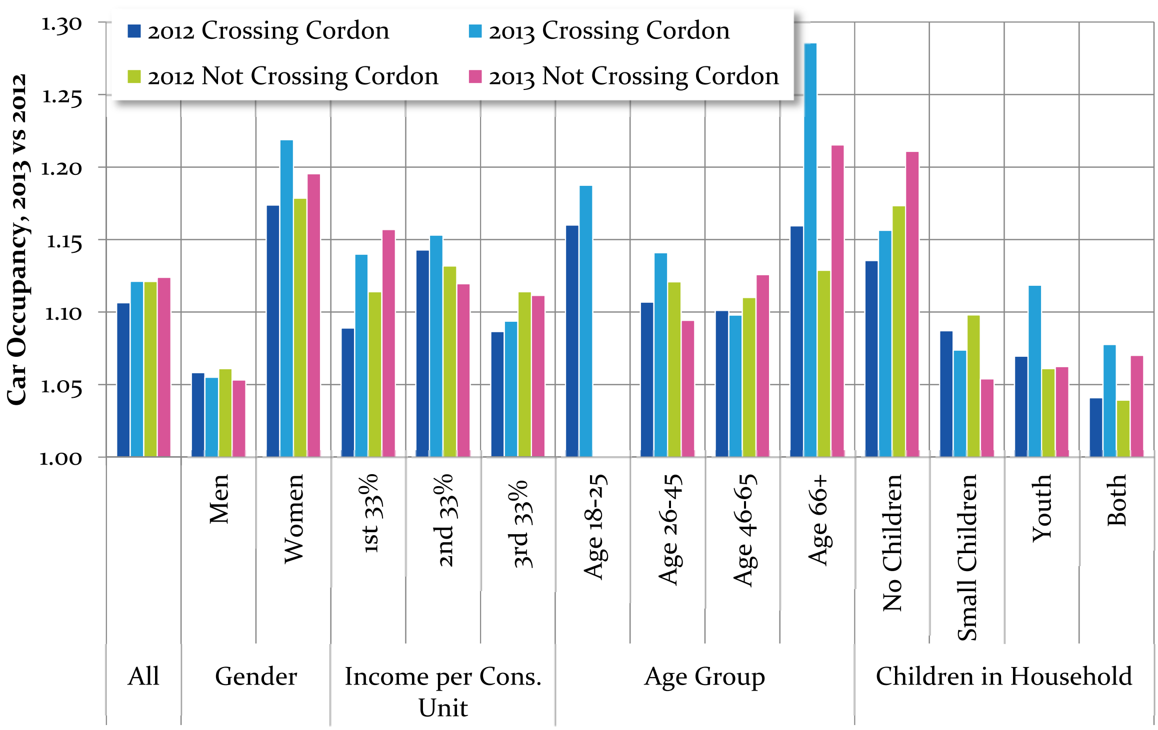

Figure 4.2 Average Car Occupancy in Gothenburg[11];
source: own calculations, using Travel Panel in Gothenburg, 2013

The increases were slightly greater among women, the lower income quantile, and all age groups except ages 46-65. For the lowest income quantile, for families with either no children or both youth and small children, and for ages 66 and up, car occupancy also increased for "unaffected" trips, which could indicate a knock-on effect of carpooling for "affected" trips leading to situations where carpooling for "unaffected" trips was also necessary.

[11] Trips *not* crossing the cordon by ages 18-25 were too few to calculate any results in either year.

4.3.3 Departure Time

The next type of adaptation is departure time choice. We focused on departure times for two kinds of trips by automobile: morning commute trips to work/school, and evening commute trips to the home on tour that earlier stopped at work/school. Morning commutes are shown in Figure 4.3, and for evening commutes in Figure 4.4. For both figures, the *x*-axis shows the averaged departure time for both observation years, while the *y*-axis shows the *change* in departure time between these years. Theoretically, we would expect to see shifts earlier in the day at the start of both peak periods, and shifts later in the day at the end of both peak periods.

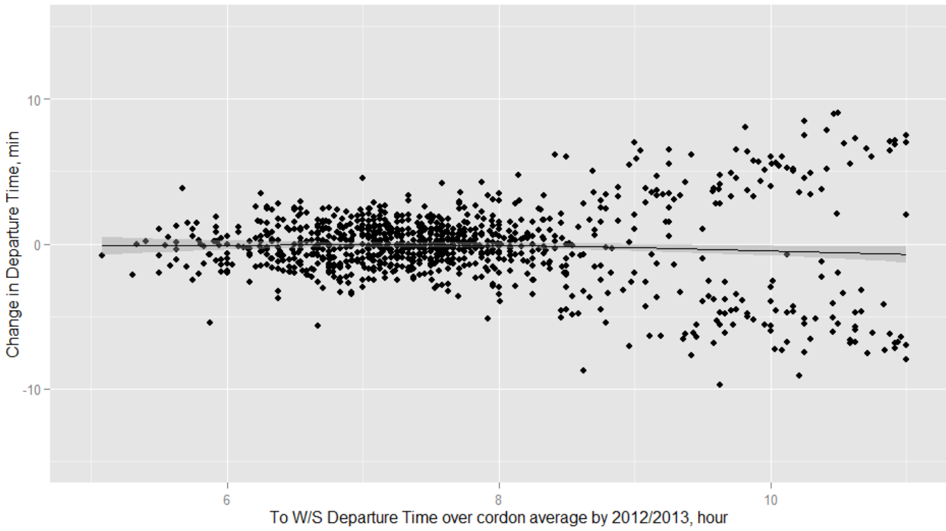

Figure 4.3 Departure Time to Work/School in Gothenburg; source: own calculations, using Travel Panel in Gothenburg, 2013

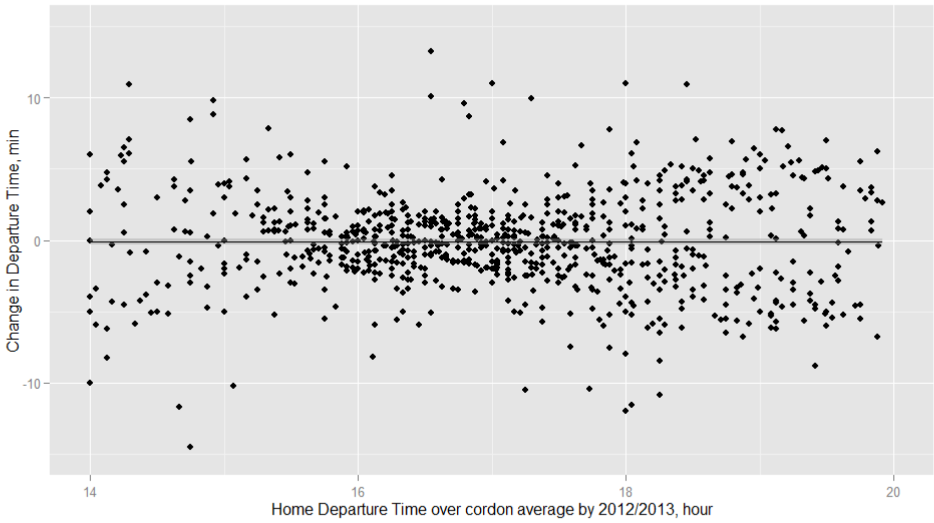

Figure 4.4 Average Departure Time Back Home in Gothenburg; source: own calculations, using Travel Panel in Gothenburg, 2013

However, while the figures show some variations in departure times between 2012 and 2013, the directions of these shifts do not follow any pattern that could be explained by the toll. While we would have expected shifts to earlier departures in the early part of the peak and shifts to later departures in the later part of the peak, what we instead see is only a slight trend of earlier departures late in the peak, which seems unlikely to be related to the toll. In addition, the absolute changes in departure time appear to be greater (as shifts in both directions) in the later part of the peak than in the earlier part. However, this is more likely due to a prevailing tendency for greater variation in departure times later in the peak, compared to earlier in the peak, regardless of whether or not the toll was in place.

The corresponding results for the return-home trip are shown in Figure 4.4. Here, we see even less of a pattern: no change in the average departure time can be seen across time of day. However, as with the morning peak, there appears to be less variation in departure time at the centre of the peak, than at the edges.

4.3.4 Trip-Chaining and Tour Lengths

To assess trip-chaining behaviour in Gothenburg, we began by computing the changes in average number of tours, differentiating between "affected" tours that at some point crossed the cordon, and "unaffected" tours that never crossed the cordon, as shown in Figure 4.5.

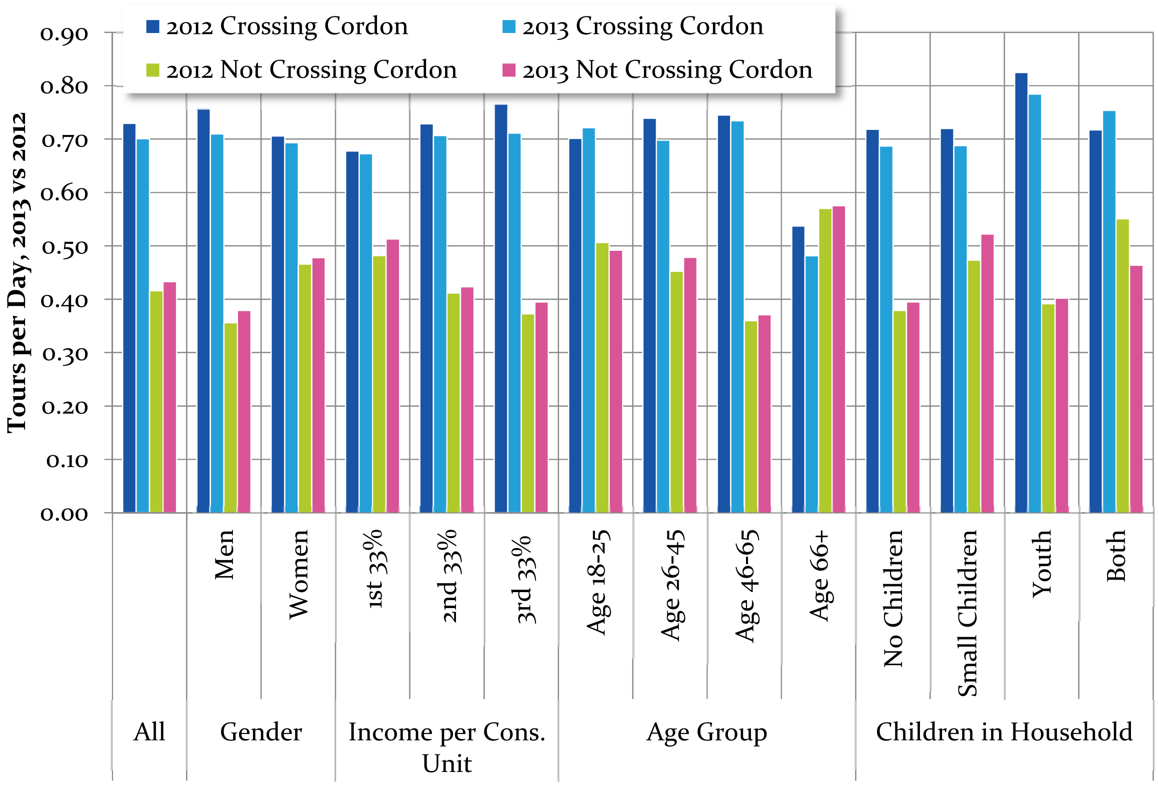

Figure 4.5 Average Number of Tours per Day in Gothenburg; source: own calculations, using Travel Panel in Gothenburg, 2013

Overall, as well as for most demographic groups, the number of tours across the cordon decreased while the number of tours not crossing the cordon increased. To the extent that these changes mirror each other, they may suggest a change of destination that avoids crossing the cordon. For some groups, men, those in the highest income quantiles, and those aged 66 and up, these reductions in average "affected" tours were not matched by an increase in average "unaffected" tours, which suggests these groups may not only be changing destinations, but also either consolidating trips (i.e. chaining together more trips), or may be eliminating some destinations entirely.

We can also compute the average number of trip segments per day, as shown in Figure 4.6. Here, we see that the average number of trip segments per day is generally reduced for "affected" but increased for "unaffected" trips. Reductions in "affected" segments are broadly similar across groups, but the increases in "unaffected" trips vary substantially, and in particular those in the middle income group do not increase unaffected trips at all, and those with small children and youth actually increase their unaffected trips.

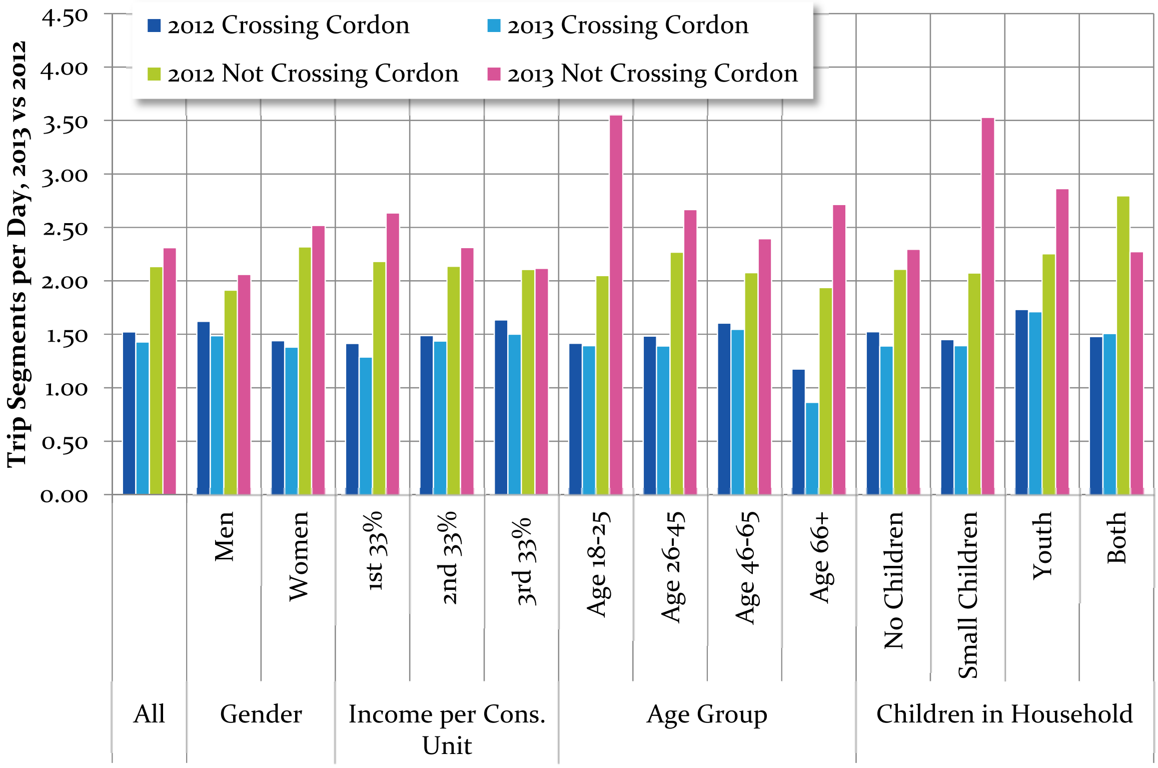

Figure 4.6 Average Number of Trip Segments per Day in Gothenburg; source: own calculations, using Travel Panel in Gothenburg, 2013

These reductions in number of trip segments could suggest that the average number of destinations is less after the introduction of toll cordons, for all groups. However, they could also suggest fewer "doubling-back" trips during the day, for example by returning home several times or by making complete sub-tours from work or school. Instead, travellers may just be consolidating trips to longer chains, without returning to the same place twice. Thus, these results further suggest increased trip-chaining behaviour.

The final indicator of trip chaining is the average number of trip segments per tour, or average tour length, shown in Figure 4.7. The results indicate that after the tolls are introduced, tours are generally composed of fewer affected trip segments, and more unaffected trip segments.

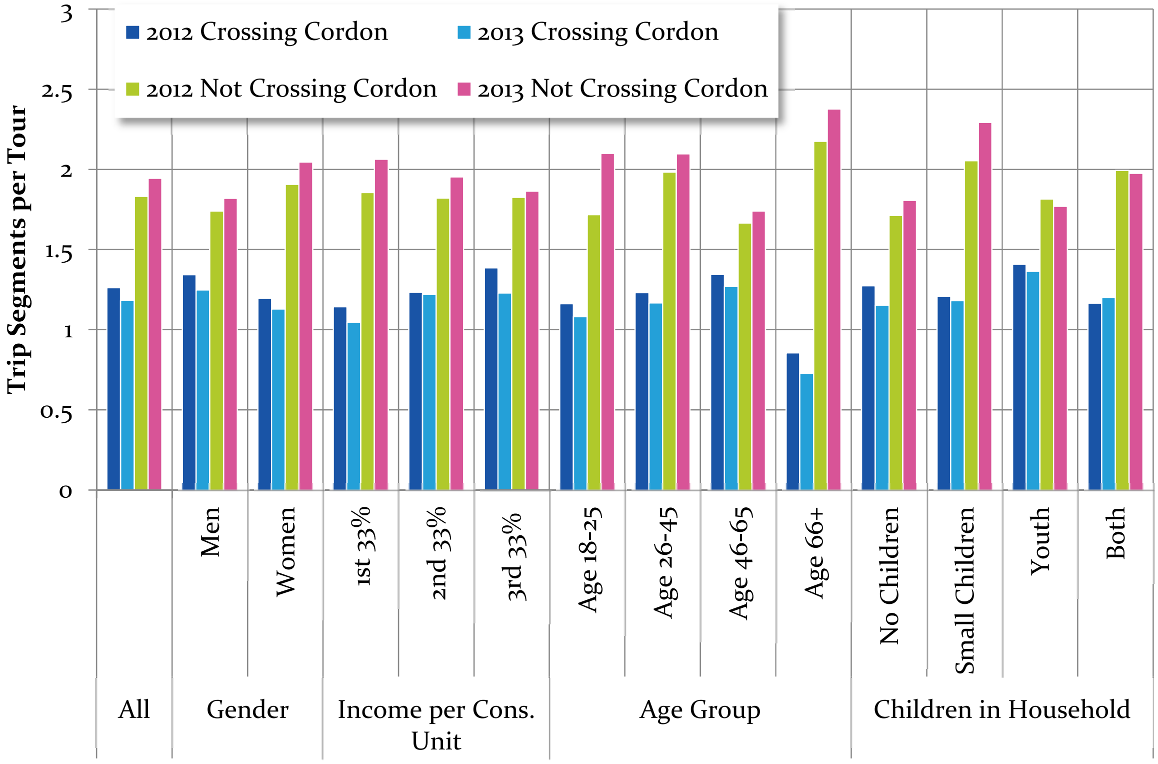

Figure 4.7 Changes in Average tour length defined as number of Trip Segments per Tour in Gothenburg; source: own calculations, using Travel Panel in Gothenburg, 2013

The results in Figure 4.7 suggest a combination of two trends: tours are chosen so as to cross the cordon to a lesser extent in 2013 as in 2012, and destination order is optimised to reduce the number of cordon-crossings necessary. Interestingly, the increases in non-crossing trip segments are generally greater than the decreases in cordon-crossing trip segments. This might suggest that the reorganized tours, while reducing the number of necessary cordon crossings, are otherwise less efficient than they previously were, in the sense of more "doubling-back" to the same location twice, thus contradicting the earlier result from the average number of trip segments. Whether or not "doubling-back" is increasing or decreasing for non-cordon-crossing trips, these combined results indicate that travellers have at least gotten more efficient in their trips across the cordon.

4.4 Review of Research Questions

The analyses above shed some light into the detailed adaptation patterns of different population groups. To summarize, we review each of the initial research questions for this work package.

RQ 2.1: Controlling for seasonal effects, to what extent do individuals and families change mode of transport when a time-differentiated road toll is introduced, and how does this compare to other adaptation responses?

The Gothenburg implementation allows us to control for seasonal effects, since the data collection was performed at the same time of year both before and after the congestion tax was introduced. The results indicated that mode shifts were very common among essentially all population groups, although to varying degrees. Overall, mode shifts appear to account for approximately 33% of adaptation responses in Gothenburg (see Table 3.2). Meanwhile, auto occupancy increases could explain roughly 16% of the adaptation responses (see Section 4.3.2). However, the examined statistics for trip chaining are not able to distinguish between pure trip-chaining effects and substitution from auto trips across the cordon to other strategies, so any statistics would surely double-count some of responses.

RQ 2.2: What is the relative magnitude of seasonal effects, compared to monetary effects, in driving choice of transport mode?

Of all of the research questions in this work package, this is the one that remains without an answer. While differences-in-differences approaches were assessed as a means of "correcting" for the seasonal effects in Stockholm, these were ultimately deemed inadequate to be able to compare seasonal effects against the specific monetary effects of the toll.

RQ 2.3: Using the targeted panel sample in Gothenburg, can any new adaptation responses be identified that could not be detected in the more limited panel sample of households from Stockholm?

Our analyses detected a wide range of adaptation responses, but one response that was much more apparent than previous analyses was the reorganisation of trip tours into longer tours, as well as other responses to reduce the number of crossings over the toll cordon. Besides this, we did not find any other adaptation responses that were completely new in Gothenburg compared to Stockholm.

RQ 2.4: To what extent do individuals respond to cordon tolls by altering the organisation of trip chains?

As mentioned above, we did detect an increase in trip chaining after the toll was introduced in Gothenburg. The results also indicated that tours crossing the cordon were to some extent replaced by tours not crossing the cordon, suggesting that some changes in destination choice occurred.

RQ 2.5: When cordon tolls are introduced in a region, do individuals within a household respond by rebalancing trip responsibilities amongst themselves, e.g. by consolidating destinations across the cordon within one person's trip chains?

When reviewing the travel survey data, it became immediately apparent that a full analysis of this question would not be possible, since that data included only individuals' travel patterns, without any information on the travel patterns of others in the household. However, it was possible to measure the extent to which these individuals more often travelled with others in the same car, using an indicator of car occupancy for car trips. This indicator found a clear trend of increasing car occupancy for trips across the cordon, suggesting that carpooling did in fact increase as a consequence of the toll. As stated above, occupancy increases could account for approximately 16% of reduced auto trips across the cordon.

5 Adaptation Mechanisms in Stockholm (Work Package 2, Part B)

Joel P. Franklin, CTS/KTH

This chapter describes an extension to previous work whereby we examine the mechanisms that drive differences in adaptation patterns across genders, ages, family types, and demographic groups. In our analysis of the Stockholm dataset, we start by comparing the responses of demographic groups when tolls were introduced in 2006. While the official evaluations and several follow-up research studies have already characterised some of the direct relationships between adaptation patterns and some SED classifications, it is still not well-understood why different groups might have had greater propensity to respond to the tolls. In this chapter, we reduce the notion of "adaptation" to its simplest form: reductions in the number of "affected" trips, in the sense of trips that by their mode, time of day, and trajectory, are subject to a toll payment after tolls are introduced.

To accomplish this we develop a series of structural equation models that help to identify and describe the effects of underlying conditions – such as socio-economic status, flexibility of work schedule, possibility for household trip bargaining, access to a car, proximity to park-and-ride lots, and proximity to public transport – on behavioural responses to congestion charges. So far this has only been done in a limited sense for Stockholm (Franklin 2013), and not at all in other cities; we build on this earlier work with more extensive explorations of possible causal networks behind adaptation responses, and we continue subsequently by studying the same for the Gothenburg road tolls.

The analysis was conducted in two stages. In the first stage we examine the mediating factors themselves to characterise their relationships with demographic factors and with trip adaptation; in the second stage, we estimate the individual contributions of the mediating factors to adaptation effects, and compare these to the direct effects of demographic factors on adaptation.

5.1 Data

The analyses contained here use data from a panel-based travel diary survey conducted in 2004 and 2006 on residents of Stockholm County (described in Smidfeldt-Rosqvist 2006). The two waves of the survey were conducted in September/October 2004 and March 2006. This mismatch of seasons was a circumstance of the congestion trial's implementation, whereby the initial start date of autumn 2005 was delayed until January 2006, and yet the trial would go no later than summer 2006, rendering impossible a second wave of data collection in autumn. As a consequence, all comparisons that have been conducted of the travel behaviour in these two waves must be qualified by the possibility that differences are due to seasonal variation in travel behaviour, rather than the congestion pricing system's effects. In total, about 24 000 individuals responded to both waves of the survey. However, to help control for seasonal variation in mode choice, in this analysis those who chose to commute by walking or bicycling in either survey wave were excluded from the dataset. After further filtering for missing data for key variables, the consequent dataset consisted of just over 16 000 individuals.

5.2 Approach

We know from earlier that the congestion tax in Stockholm generally caused reductions in trips by car across the cordon, and we also know that certain demographic groups—for example, women and lower incomes—reduced their trips more than others. If we were to assume that these different groups did not have an "intrinsic reason" to reduce their trips more than others, then there must be some specific feature of the situation in which these people find themselves, that leads to them showing a stronger response.

For this study, we compare the population across three demographic dimensions, which we identify as the "independent variables":

- Gender
- Age
- Income per consumption unit (computed in the same way as in described in Section 3.4.3), referred to henceforth in this chapter as simply "income"

The basis of comparison for all results is the number of auto trips made across the cordon during the tolled period on the study day, which we identify as the "dependent variable". This factor efficiently identifies one of the key responses in behaviour, which is whether to reduce the number of trips for which the mode, time of day, and trajectory would in 2006 involve paying a toll. Hence, it does not differentiate between different alternative behaviours, but it does measure the total extent to which travellers either decide to pay the toll or to change their behaviours.

The central approach here was to identify a series of possible "mediating factors" that could account for these differences in responses. Using the panel travel survey as a basis, we identified a series of four factors that could have mediated the effect of the congestion tax on car trips across the cordon for these groups:

- "Cordon-Crossing": home and work location on opposite sides of the cordon (0 or 1)
- "Flex-Time": flexible work hours (0 for "never", 0.5 for "sometimes", and 1 for "always")
- "SL Card": having access to a long-term public transport card (0 or 1)
- "Access to Car": having access to a car in the household (0 or 1)

This list is far from comprehensive – other potential mediating factors certainly exist, but we are limited to the data collected in the panel survey. For example, the availability of a company car could have a crucial effect on whether individuals were affected by the congestion tax, since in most cases the company would then bear the burden of paying the tax. This is especially relevant to comparisons across demographics, since company cars are to a far greater extent available to those with higher-paying jobs. Other possible mediating factors that are missing here include differences in the schedule constraints of non-work destinations (e.g. penalties for late pickups at day-care), employer-subsidized parking at the workplace, walking access to the public transport network, and household structure.

The dataset was restricted to include only individuals who reported making at least one affected trip on the study day. This focus was found to be essential because the individuals who made at least one affected trip in 2004 were exactly the same as those who made at least one such trip in 2006; hence, there was no sensitivity between zero affected trips and some affected trips, and including them would risk large bias in the parameter estimates.

The analysis of mediating factors uses structural equations modelling to estimate the strengths of associations between a set of independent variables, a set of dependent variables, and a set of mediating factors that are hypothesised to both be affected by the independent variables and to affect the dependent variables, forming an indirect effect between the independent and dependent variables. The structural equations model enables the strengths of indirect effects to be compared to each other and to the strength of the direct effect.

Indeed, in the case of the differential effects of the congestion tax on demographic groups, there is little theory to support the idea that these effects are truly direct, in the sense that these groups are intrinsically different from each other with respect to the charges. Rather, theory suggests that certain groups have a propensity to find themselves in particular circumstances that either amplify or dampen their responses to the congestion tax. As long as the particular circumstances of certain groups remain unidentified and unmeasured, then they will appear to be "direct effects".

However, in this study by estimating the strength of the four hypothesised mediating factors listed above, the scale of direct effects can be reduced. What remains in the direct effects is either an intrinsic difference between groups or a proxy for other mediating factors for which data is not available.

The direct effects are found directly as parameters in the structural equations model. The indirect effects, however, must be computed from the components of the mediating factors:

$$\begin{aligned} &Total\ Effect = Direct\ Effect + Indirect\ Effect \\ &= Direct\ Effect + \sum_{Each\ Mediating\ Factor} Stage\ I\ Effect * Stage\ II\ Effect \end{aligned}$$

where, *Stage I Effect* is the parameter indicating the effect of the independent variable on a mediating factor, and *Stage II Effect* is the parameter indicating the effect of a mediating factor on the dependent variable.

5.3 Results

To introduce the results of the analysis, we start with the partial findings for how our four mediating factors changed between 2004 and 2006. We then continue by presenting the results for each demographic factor. For each dimension, we start by characterising the overall trend in terms of number of "affected" per day, by which we mean the number of trips that would be tolled in 2006, given the trip's mode, time of day, and trajectory (i.e. car mode, during toll hours, and crossing the cordon). For the number of affected trips per day in 2004 and 2006, we assess the extent to which behaviour is explained by the four mediating factors given in Section 5.2. We follow this by an assessment of the difference in average number of affected trips per day, before and after tolling, and how much of this difference can be explained by the mediating factors.

5.3.1 Mediating Factors

We start by extracting the direct effects on, and of, the four mediating factors on "affected" trips, i.e. auto trips across the cordon per day during the peak hours. As shown in Figure 5.1, males on average (holding age and income constant) have roughly 2%-points greater chance of having access to a car and 3%-points greater chance of having flexible work schedules, while they have 4%-points lesser chance of possessing an SL card and 2%-points chance of commuting across the cordon, compared to females. Similarly, each 10 years of age (holding gender and income constant) is associated with about 2%-points greater chance of having flexible work hours and 8%-points lesser likelihood of having flexible work hours, while the effects on access to a car and possession of an SL card are negligible. Finally, each additional 10 000 SEK in income (holding gender and age constant) is associated with 5%-points greater chance of having flexible work hours, but only very small differences in the other mediating factors.

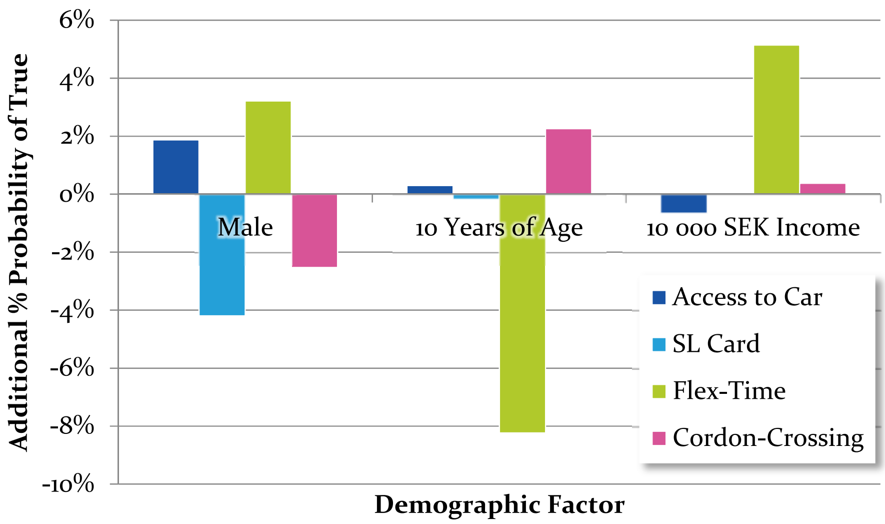

Figure 5.1 Average Effects of Demographic Factors on Mediating Factors; source: own calculations, using the Stockholm Travel Panel, 2006

Next, we show in Figure 5.2 the associations of these same mediating factors with affected trips. The effects vary somewhat in direction, such that in 2004, without tolls, greater affected trips are associated with access to a car, flexible work hours, and commutes across the cordon. Interestingly, the results for 2006 all indicate either a weakening or a reversal of the effect seen in 2004. Firstly, access to a car is less strongly associated with affected trips in 2006, although still positive, suggesting that those with only irregular access to car were less sensitive to the toll, perhaps because those irregular occasions were yet important to continue as they were. The “effect” of possessing an SL card was suppressed and perhaps reversed, which could actually suggest a reverse causality where some of those making more affected trips were incited to obtain an SL card. As to flex-time, the diminishing and reversing effect indicates that those with flexible work hours, despite having more affected trips in 2004, were more able to shift their trips in 2006 – presumably to outside the peak period. Finally, those commuting across the cordon were found to make fewer affected trips in 2006 compared to others, a reversal of 2004; this could indicate that commute trips are easier to shift than other types of affected trips.

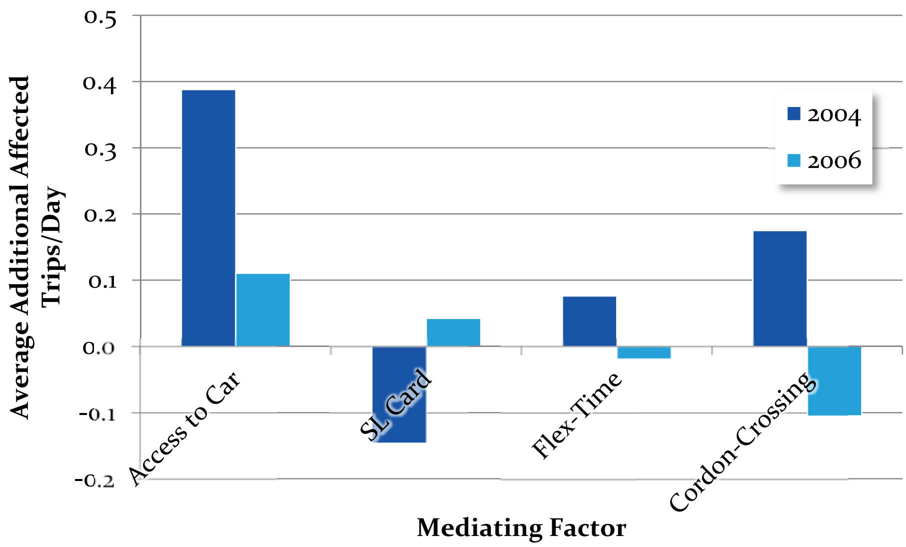

Figure 5.2 Average Effects of Mediating Factors on Trips in 2004 and 2006; source: own calculations, using the Stockholm Travel Panel, 2006

5.3.2 Combined Effects

Finally, we combine the indirect effects, which follow from the above results relating to mediating factors, together with the direct effects between demographics and the number of affected trips. We now continue by taking Gender, Age, and Income in more detail.

5.3.2.1 *Gender*

The effects of gender on the number of tolled trips in 2004 and 2006 are shown in Figure 5.3. The *x*-axis is divided between the "partial" effects and the "total" effect, and the *y*-axis is expressed as a difference in average tolled trips made males, compared to females. Here, we see a familiar trend that males make more tolled trips than females in both years, though as with previous research, the average difference is small in magnitude: roughly 0.15 more trips/day made on average by males than by females in 2004, and 0.20 more trips in 2006.

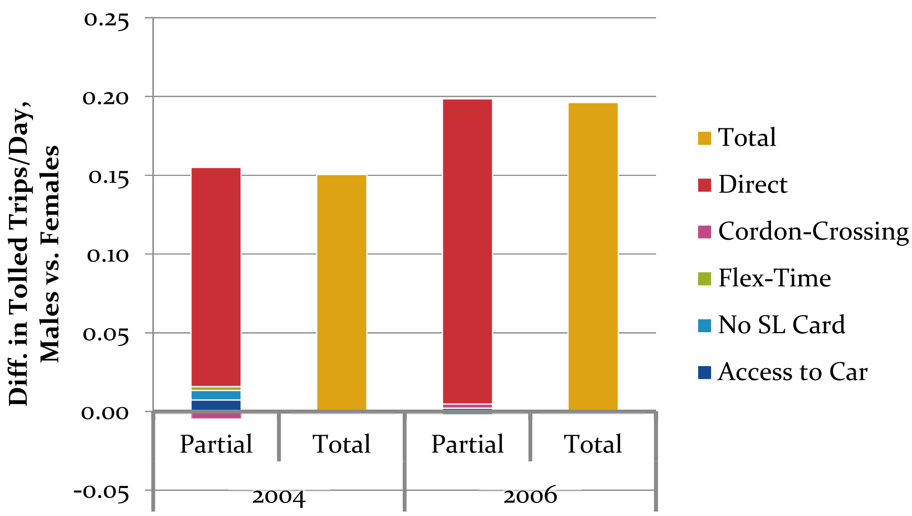

Figure 5.3 Difference in Tolled Trips by Gender in Stockholm; source: own calculations, using the Stockholm Travel Panel, 2006

Focusing now on the multi-coloured bar, we see a breakdown of the mechanisms behind this difference: this gender effect is almost entirely due to direct effects, which indicates that the four mediating factors explain rather little. While differences in males' and females' access to car and to a public transport card might explain a small part of this difference, most of the effect remains unexplained and hence is seen as a direct effect between gender and tolled trips.

Now if we focus on just the difference in tolled trips between 2004 and 2006, then we obtain the results shown in Figure 5.4. The y-axis is in the same units, but now this expresses a *difference-in-differences*: specifically, the *change* in the *difference* between males and females, from 2004 to 2006. Here, we see in the "Total" column that the gender effect was greater by 0.045 trips/day in 2006 compared to 2004—that is, the difference-in-differences between genders was very small after the congestion tax was introduced. This small change is a combination of effects in two directions, as shown by the "Partial" column: most of it appears due to an increase in direct (unexplained) effects. To be sure, there were some statistically significant mediating effects, but these were overwhelmed in magnitude by the direct effects.

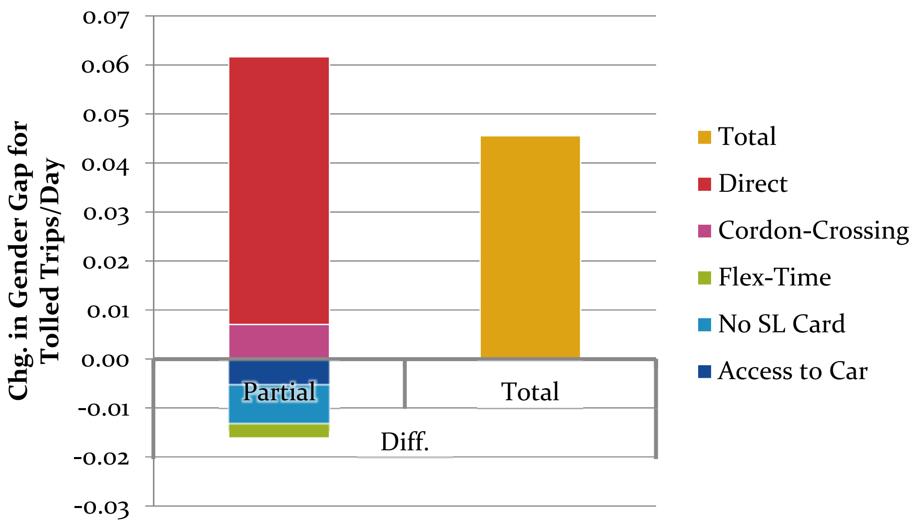

Figure 5.4 Changes in Gender Effect (2004 to 2006) on Tolled Trips in Stockholm source: own calculations, using the Stockholm Travel Panel, 2006

5.3.2.2 *Age*

As to the relationship between age and tolled trips, in 2004 there was essentially no overall relationship between age and affected trips (see Figure 5.5). This is despite the detection of several mediating effects that, while significant, worked in opposite directions and cancelling each other out. In 2006, however, an effect appeared where each decade of age was associated with 0.03 fewer affected trips per day. The difference seems to be due to direct effects in 2006 that did not appear in 2004, as confirmed by the results in Figure 5.6, which show what part of the change was explained by direct effects and mediating effects.

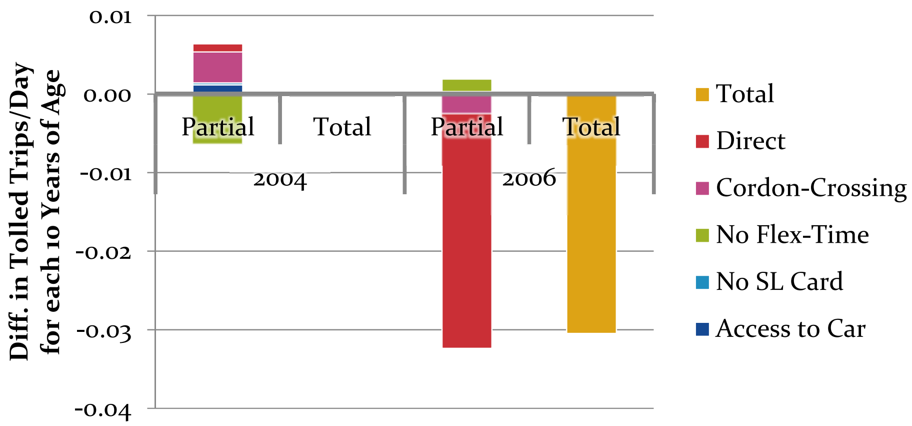

Figure 5.5 Difference in Tolled Trips per 10 Years of Age in Stockholm; source: own calculations, using the Stockholm Travel Panel, 2006

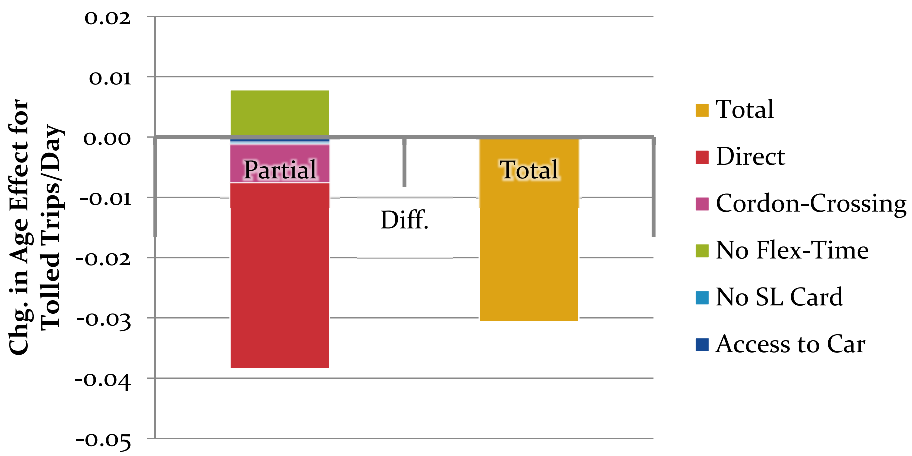

Figure 5.6 Changes in Age Effect (2004 to 2006) on Tolled Trips in Stockholm; source: own calculations, using the Stockholm Travel Panel, 2006

5.3.2.3 *Income*

Finally, the relationship between income and tolled trips shows a tendency for higher-income individuals to make slightly fewer affected trips on average in 2004, as shown in Figure 5.7. This is in fact a surprising result, which differs from much previous literature. However, it is important now to note the consequences of focusing only on individuals making at least one affected trip. Had we included all individuals, then this result would also incorporate income differences between those who make no affected trips, and those who make at least one affected trip, and consequently the difference would be on the order of 0.02 *more* affected trips per day, per 10 000 SEK in monthly income. So, the results shown here illustrate a tendency only among a specific group of individuals. In 2006, this tendency diminishes significantly, leaving only a tendency for each 10 000 SEK in monthly income to be associated with 0.01 fewer affected trips. Examining this difference as shown in Figure 5.8, we see that it is nearly entirely explained by direct effects, and hence not strongly explained by the four mediating factors.

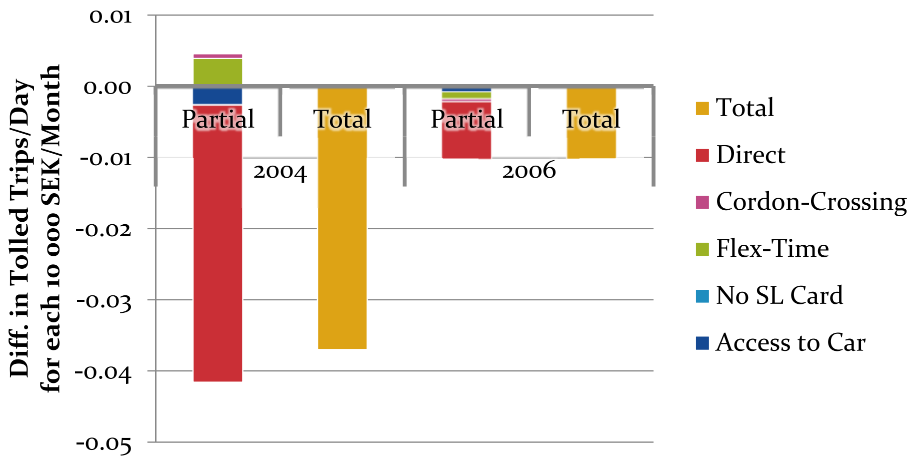

Figure 5.7 Difference in Tolled Trips per 10 000 SEK/Month Income in Stockholm; source: own calculations, using the Stockholm Travel Panel, 2006

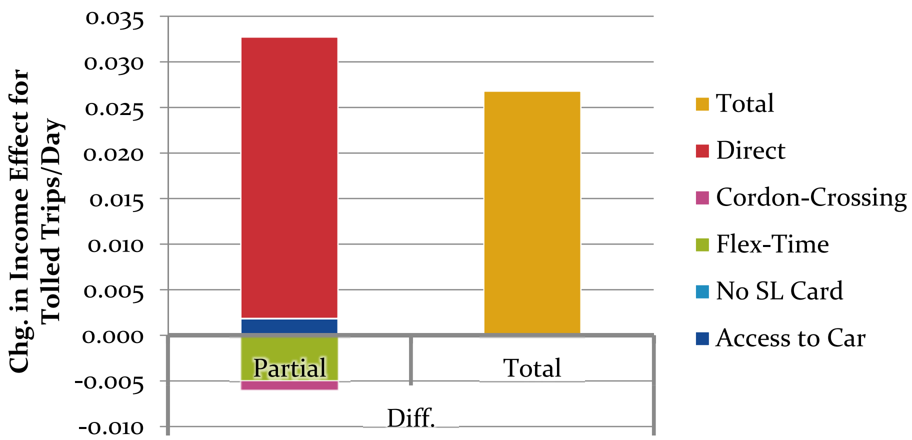

Figure 5.8 Changes in Income Effect (2004 to 2006) on Tolled Trips in Stockholm; source: own calculations, using the Stockholm Travel Panel, 2006

5.4 Discussion

Overall, the results above suggest that the four mediating factors considered here were not significantly associated with either the gender-related or the income-related differences in average affected trips per day. Even for age-related effects, where mediating factors were found to be substantial, the estimates indicated that these effects worked in opposite directions. In other words, as individuals get older, on the one hand they are more likely to commute across the cordon (leading to more affected trips in 2004), but on the other hand they are less likely to have flexible work schedules (leading to fewer affected trips in 2004); consequently there is no overall relationship between age and number of affected trips in 2004.

For the other mediating factors, the scale of effects was even smaller. However, this is not to say they were insignificant. All of the results above were found to be statistically significant, with the exception of the role of SL Card possession as a mediating factor for Income. But this significance was reduced practical importance, by the sheer indirectness of the mechanisms under study here.

As an example, we did see here that higher income is associated with flexible work hours, with probability of flex-time increasing by 5%-points for each additional 10 000 SEK/month, on average (see Figure 5.1). This magnitude is rather unsurprising, as it roughly approximates the sample's shares with flexible work hours for three income quantiles: 45.2% for incomes under 25 000 SEK, 63.9% for the next incomes up to 41 000 SEK, and 65.4% for the top tier of incomes. At the same time, flexible work hours are associated with a slight increase of 0.075 additional affected trips per day, on average. This, again, is a reasonable magnitude. However, when combining these to estimate the indirect effects of income on affected trips, mediated by flexible work hours, these combine to represent only 0.004 additional affected trips for each 10 000 SEK in income.

The main conclusion is that mediating factors exist, but that their indirectness of effects means that they play an extremely small role in differences between different demographic groups. These

5.5 Review of Research Questions

The analyses above seem to rule out several possible factors that might have explained the different levels of adaptation for different groups. To summarize, we review each of the initial research questions for this work package.

RQ 2.6 and RQ 2.7: What underlying conditions lead to individuals and households choosing different adaptation responses to cordon tolls? Can the differences in preferred responses across SED groups be explained by other circumstances such as home and work location, constraints at home and work, household structure, auto ownership, etc.?

These two research questions can be addressed together. The analysis of underlying conditions found that access to a car, possession of a public transport card, and crossing the toll cordon between home and work, all contributed in different ways to the extent to which different demographic groups adapted to the tolls, rather than choosing to pay for tolled trips. Flexible work times, on the other hand, were found not to play an important role.

RQ 2.8: Given a pattern of causality among SEDs, circumstances, and adaptation responses, what kinds of mitigation measures would be most effective in compensating for differential effects of cordon tolls across SED groups?

Based on the results from the entire work package (reported in both Chapters 4 and 5), we can speculate on some strategies for mitigating the effects of cordon tolls. We base these suggestions on the principle that the best mitigation policy will reduce the burden of adaptation, by making an individual's second-best alternative, after driving across the toll cordon during the charging period, as attractive as possible.

First of all, we found in Section 3.4.2 that one of the most prevalent adaptation responses was changing mode. This suggests that, consistent with much policy research round congestion pricing, investments in public transport and infrastructure for other modes, such as walking and cycling, could be effective mitigation. Second, the finding that car occupancy increased after the tolls were introduced in Gothenburg suggests that policies to ease the burden on high-occupancy vehicles should be considered, such as by reducing the level of the toll for these vehicles. However, such a system would be technically difficult to implement in such cities as Gothenburg and Stockholm, where the toll is assessed based on licence-plate recognition technology.

The multiple findings that trip tours were reorganised in response to the tolls in Gothenburg suggest that travellers could possibly benefit from improved services to optimise trip schedules, such as online and mobile trip navigation tools. Indeed, such tools are already widely available across Sweden.

One possible mitigation strategy that we do not recommend, based on the findings here, is a change in the charging schedule of fares across time of day. It was clear that different groups responded to a different extent in their departure times to work/school and back home again. However, this kind of differentiation in departure times is essential if congestion pricing is to have its intended effect. Hence, we advocate setting the toll schedule fully on the basis of congestion mitigation and using other measures to ease the burden of alternative travel options.

6 Adaptation Patterns and Attitudes in Trondheim (Work Package 3)

Farideh Ramjerdi, Kåre Skollerud, Jon Martin Denstadli and Tanu Priya Uteng, TØI

This chapter reviews the results of an analysis of observed travel behaviours, stated responses, and expressed attitudes in the context of the toll ring in Trondheim, Norway, where tolls have been in place, in one form or another, since 1991, aside from a five-year gap in the 2000's. The analysis of attitudes also makes comparisons to attitudes seen toward the toll ring in Oslo, Norway.

Trondheim is a city and municipality in the Sør-Trøndelag County in Norway. The city is situated to the south of the crossing of river Nidelva with Trondheim Fjord. The city has mainly developed along two corridors in the south and east directions, with a population of 182 000 in 2014. The population of the greater Trondheim region is estimated at 250 000. Trondheim is the third most populous municipality and the fourth largest urban area in Norway. The city functions as the administrative centre of Sør-Trøndelag County.

A number of universities and research institute are located in Trondheim. The city's population increases by approximately 10-15 percent during the school sessions, which makes travel behaviour in Trondheim more subject to seasonal change than in other cities.

A cordon toll scheme was originally introduced in 1991 for financing a package of road (about 80%) and public transport (about 20%) projects, but the scheme was abandoned in 2005. It was reintroduced in 2010. The scheme was reintroduced in 2010 and significantly modified in March 2014 to a cordon toll. This was seen as an "environmental scheme", in the sense that the proceeds from the environmental package should be equally divided between road and public transport. In general, toll schemes in Norway are based on local initiatives and approval by the parliament rather than on referendum.

6.1 Background

The scheme that was abandoned in 2005 comprised of 18 toll stations. Figure 6.1 shows the locations of the toll stations. Inbound traffic was subject to the toll Monday through Friday from 6.00 a.m. to 5.00 p.m. The toll fee in 2005 was NOK 15 for light vehicles at the manual stations. With a prepayment arrangement, the toll fee was between NOK 9-14 during rush hours and NOK 6-11 between rush hours.

Meland and Polak (1993) report that the overall impacts of the toll ring were quite small. The number of the toll stations in the scheme that was reintroduced in 2010 were 8 and it was increased by 14 toll stations in March 2014, with the 22 toll stations forming a cordon around the city centre. The location of the toll cordon is quite similar to the scheme that was abandoned in 2005. Figure 6.2 shows the locations of toll stations in 2010 and 2014.

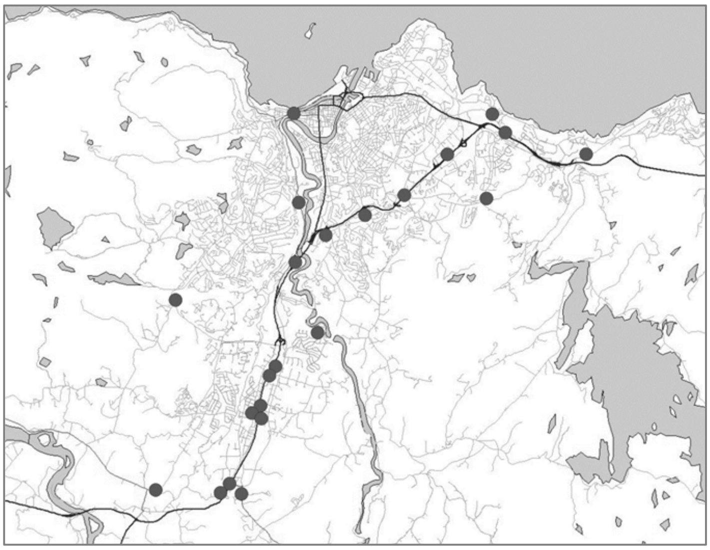

Figure 6.1 Location of toll stations in Trondheim in 2005

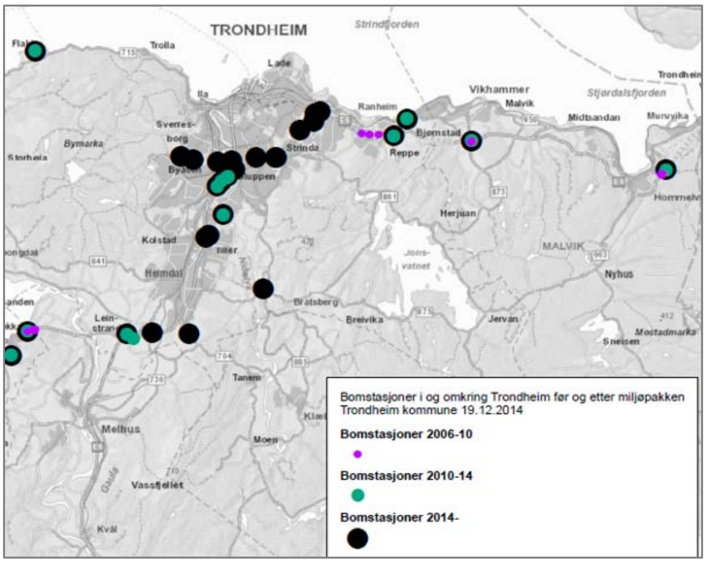

Figure 6.2 Location of toll stations in Trondheim in 2010 and 2014

In both the 2010 and 2014 schemes, collection takes place around the clock, seven days a week. It is also put in a rush-hour premium: the price is double during the periods 07-09 and 15-17. The toll fee is NOK 10 normally and NOK 20 on weekdays at 07-09 and 15-17. The maximum toll payment is limited to 110 toll crossings per month.

The research questions that work package 3 responds to are:

- RQ 3.1: To what extent do road tolls impact spatial and time distributions of travel in the short and medium term?
- RQ 3.2: Do people consider road tolls in decisions related to housing location, choice of school/kindergarten, and automobile ownership?
- RQ 3.3: Have improvements in public transport reduced the perceived disadvantages of road tolls?
- RQ 3.4: Do road tolls increase employees' propensity to conduct ICT-based work from home?
- RQ 3.5: Are resident attitudes toward road tolls determined by the type of scheme implemented (time-differentiated vs. fixed tariffs)?
- RQ 3.6: Do adaptation patterns and attitudes vary by households'/individuals' demographic background, household type, location, and other factors (e.g., car access, access to public transport, working hours, kindergarten use, etc.).

The analyses of the impacts of the Trondheim toll scheme on spatial and time distributions of travel in the short and medium runs (RQ3.1) are based on Norwegian National Travel Surveys of 2010 (before and after the introduction of the scheme on March 31, 2010) and 2014 (before and after the introduction of the scheme on march 17, 2014). A new survey was conducted in Trondheim in June 2014 to address research questions RQ3.2-RQ3.6.

6.2 Impact of the 2010 and 2014 Trondheim scheme on travel behaviour

The analyses of the impacts of the Trondheim on travel behaviour are based on the Norwegian National Travel Surveys of 2009/2010 and 2013/2014. Both these surveys were conducted by telephone. The respondents, all over age 13, received the questionnaire by post a few days before they were contacted by telephone. The questionnaire includes travel diaries for an assigned day of travel, and for the previous month for long distance trips. The respondents received instructions on how to fill in their travel diaries, and in particular, they were reminded to include their shorter walk trips. In addition to travel diaries, information on respondents' demographic characteristics and about their households were collected in these surveys. Both surveys were carried out around the year in order to address seasonal variations in travel behaviour. A representative national sample of 10 000 and an additional local sample were collected in the 2009/2010 and 2013/2014 surveys. The additional sample for the Trondheim region was about 6000 in the 2009/2010 survey and 4590 in the 2013/2014 survey. The response rate was 46% in the 2009/2010 survey and 20% in the 2013/2014 survey. A major limitation of these surveys is the total number of observations: it does not lend itself to the necessary number of trip segments required in this study. The analyses are hence confined to:

1. Shifts in mode choice
2. Shifts in departure time
3. Changes in tour frequency

Since the number of observations in the Norwegian National Travel Surveys is not sufficiently large, we were constrained with the number of sub-groupings. The sub-groupings used in the analyses of mode shifts were made along the following dimensions:

4. Discretionary and compulsory trips
5. Gender
6. Income
7. Education

The periods before and after the introduction of the scheme are referred to as period B and period A, respectively. The zones inside and outside the toll ring are referred to as zone I and zone II, respectively.

Figure 6.3 shows the locations of zone I (in green) and zone II (in orange) and with respect to the locations of the toll stations.

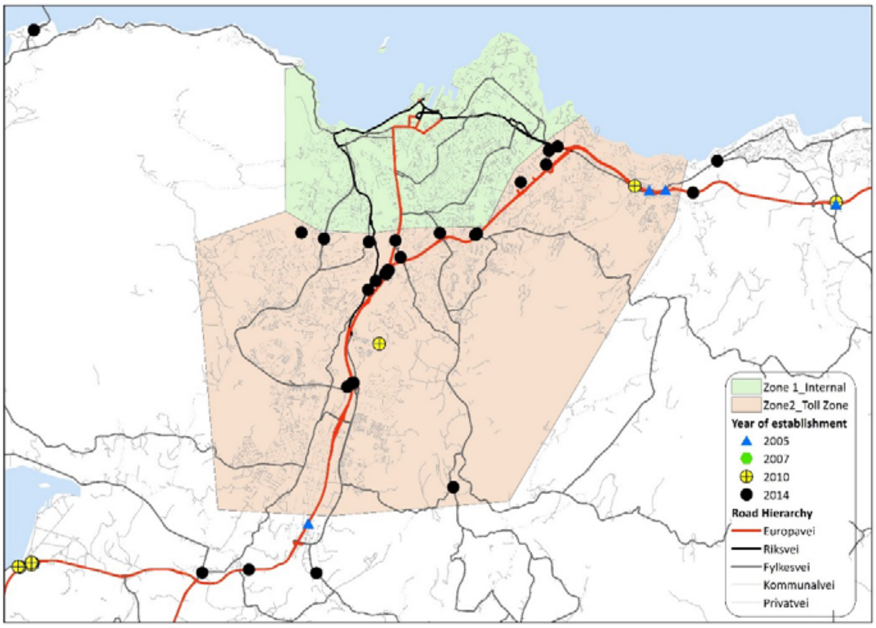

Figure 6.3 Locations of zone I and zone II with respect to the cordon toll

6.2.1 Impacts of the 2014 toll scheme

6.2.1.1 Impacts of the 2014 toll scheme on mode shifts

The toll schemes in 2010 and 2014 in Trondheim were introduced as environmental scheme. The toll schemes were introduced in the second part of March, during a transition stage between seasons. In addition, the school year ends in mid-June. Trips that cross zones I and II are affected by the toll scheme. In order account for seasonal change on travel behaviour and the end of the school year, the changes in travel behaviour within zone I and zone II are used as a control group. Figure 6.4 and Figure 6.5 show changes in mode shares of trips within zones I and II (not crossing the cordon toll), respectively, from before, to after, the new toll scheme was introduced.

Figure 6.4 Changes in mode shares of trips within zone I of work and discretionary trips; source: Norwegian National Travel Survey of 2014

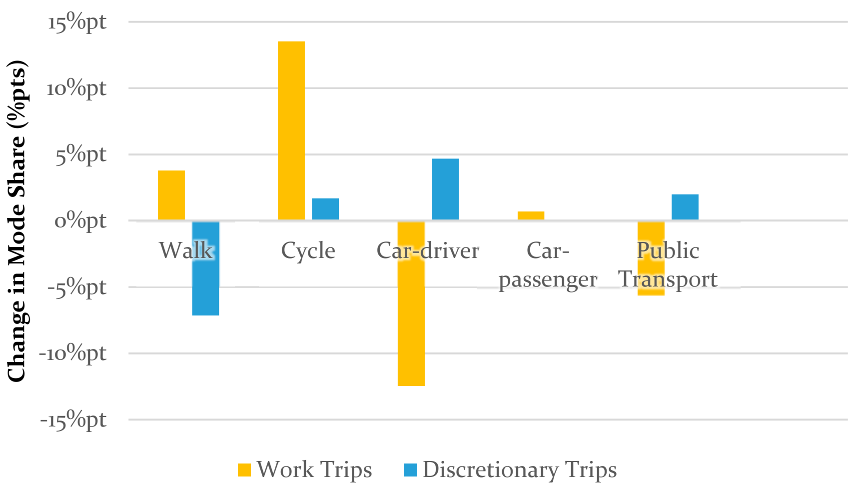

Figure 6.5 Changes in mode shares of trips within zone II of work and discretionary trips; source: Norwegian National Travel Survey of 2014

An examination of Figure 6.4 and Figure 6.5 indicates that there have been visible changes in mode share for trips that did not cross the toll ring after the end of March 2014. It would be safe to assume that the shifts are not related to the introduction of the 2014 scheme, but rather due to seasonal change in Trondheim. The significant changes are specific to modes cycle and public transport. While cycle mode share increased, public transport mode share decreased for internal trips in both zones.

Figure 6.6 shows the changes in mode shares in percentage points (absolute changes in mode share) for trips that crossed the toll ring, as the result of the 2014 toll scheme. This figure also indicates that cycle mode share increased, while mode share for public transport decreased. The shifts are similar to the corresponding shifts for internal trips in zone I.

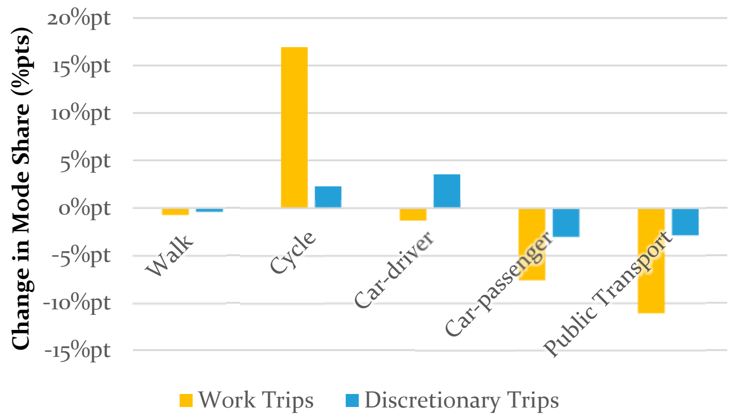

Figure 6.6 Shifts in mode shares of trips that cross the toll ring as the result of the 2014 toll scheme; source: Norwegian National Travel Survey of 2014

The analysis of trip lengths for internal trips in zones I and II and for the trips that cross the toll ring shows that with respect to trip length distribution, internal trips in zone I (inside the toll ring) and the trips that cross the toll ring are rather similar. Assuming that the mode shifts of the internal trips in zone I capture the seasonal effects, it is possible to evaluate the net effect of the scheme on the mode shift of the trips that cross the toll ring. The toll scheme does not seem to have a significant impact on the mode shifts.

Figure 6.7 through Figure 6.9 show the resulting mode shifts for groupings income, gender and education for trips that cross the toll ring, as the result of the scheme in 2014.

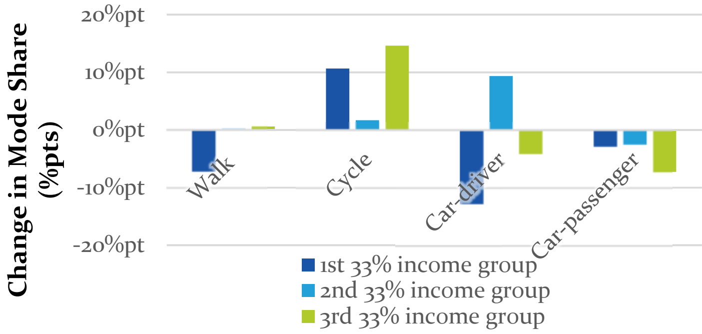

Figure 6.7 Changes in mode shifts for trips that cross the toll ring for 3 income groups; source: Norwegian National Travel Survey of 2014

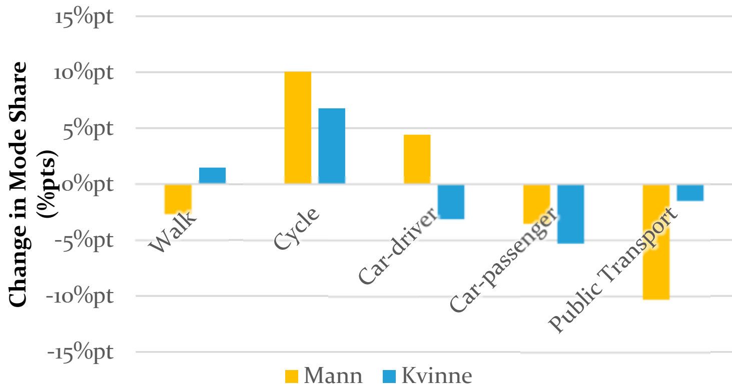

Figure 6.8 Changes in mode shifts of trips that cross the toll ring for men and women; source: Norwegian National Travel Survey of 2014

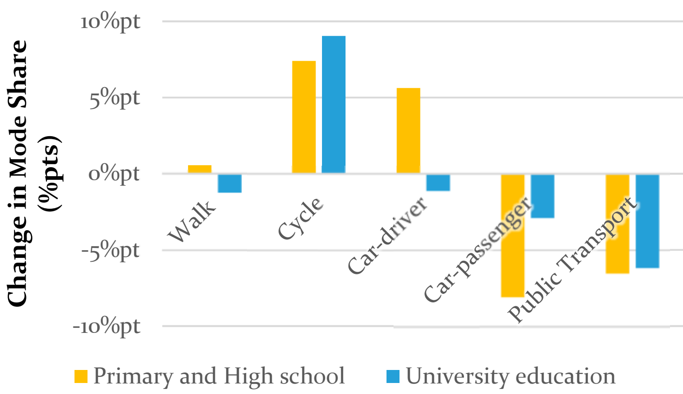

Figure 6.9 Changes in mode shifts of trips that cross the toll ring for low and high education groups; source: Norwegian National Travel Survey of 2014

Similar analyses were performed for these groupings for trips within zone I (inside the toll ring) and trips within zone II (outside the toll ring). The comparison of the changes makes it difficult to suggest any significant change for these groupings.

The municipality of Trondheim conducted a mini travel-behaviour survey to analyse the modal shifts in 2014. The mini survey confirms the findings presented earlier in this section on shifts in mode share.

6.2.1.2 Shift in Departure time

Figure 6.10 shows the changes in departure times for all trips by car that cross the toll ring before and after the 2014 scheme for work trips. Figure 6.11 shows the corresponding changes for work trips. An examination of these figures indicates that there were no significant changes in the departure times of the trips made in the morning as the result of the 2014 scheme. It however seems that the departure time of trips in the afternoon is changed to just before 17:00 when toll fee is higher. The shift is more pronounced for all trips than for work trips. An explanation is related to the 2014 toll scheme where both inbound and outbound traffic is tolled, with higher level of toll fee during the rush hour period. The results could have been different if only inbound traffic were charged at 20 NOK, and if there were no toll fee after the rush hours.

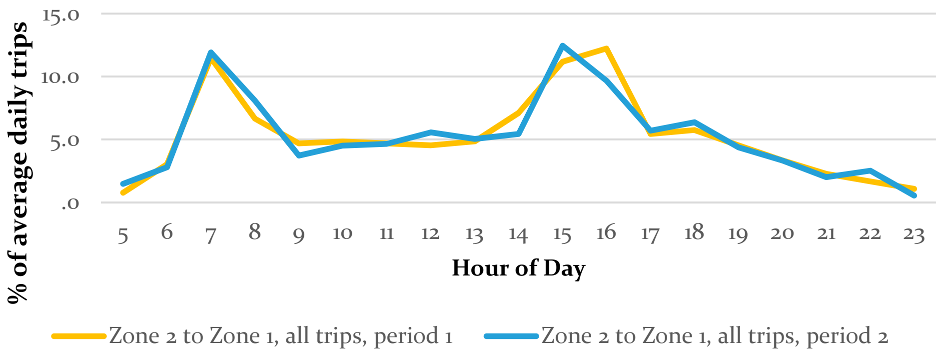

Figure 6.10 Changes in departure time for all trips by car crossing the toll ring due to the 2014 scheme; source: Norwegian National Travel Survey of 2014

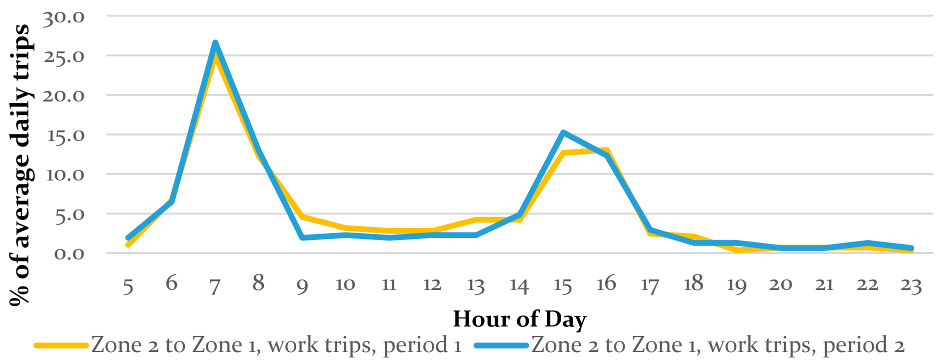

Figure 6.11 Changes in departure time work trips by car crossing the toll ring due to the 2014 scheme; source: Norwegian National Travel Survey of 2014

6.2.1.3 Trip frequency

The impacts of the 2014 toll scheme on car trip frequency were analysed by comparing the daily car trips that cross the toll ring as a percentage of the total daily car trips, including those that cross the toll ring, before and after the introduction of the toll scheme. Table 6.1 shows the results. There were significant and similar changes in the trip frequency for both internal trips and for the trips crossing over the zones. This indicates that the tolls scheme did not have significant effect on trip frequency. The changes in trip frequency is mainly attributed to the seasonal change.

Table 6.1 Changes in trips frequency before and after the 2014 scheme; source: Norwegian National Travel Survey of 2014

Trips crossing the toll ring			
Period	**Total daily car trips crossing the toll ring**	**Total car trips**	**Percentage**
Before	662	2503	26 %
After	509	1964	26 %
Internal trips in zone I			
Period	**Total number of trips within zone**	**All trips**	**Percentage**
Before	1431	2503	56 %
After	815	1964	54 %
Internal trips in zone II			
Period	**Total number of trips within zone**	**All trips**	**Percentage**
Before	917	2503	37 %
After	663	1964	34 %

6.2.2 Impacts of the 2010 toll scheme

The toll scheme in 2010 was introduced on March 31. The analysis of the impact of the 2010 scheme on travel behaviour is carried out in a similar manner to those carried out for the 2014 scheme. We do not expect the impacts of the 2010 scheme to be more than the impacts of the 2014 scheme. The analyses confirm our belief.

The scheme in 2010 did not use a closed cordon around the city centre. For the evaluation of the medium- to long-term impacts of the scheme, we rely on the definition of the two zones that were defined for the analysis of the 2014 scheme; inside and outside the toll ring.

Figure 6.12 shows the impacts of the 2010 scheme on the mode shares of the trips that cross the zones identified as inside the toll ring and outside the toll ring in 2014. The results can be compared to impacts of the 2014 scheme on mode share shifts (Figure 6.6). We see a similar pattern of shifts in 2010 and 2014, the latter shown in Figure 6.13. What makes the impacts different is the extent of the shifts to cycle in 2014 compared to 2010. This can be explained by the extent of investments in cycling infrastructure in Trondheim.

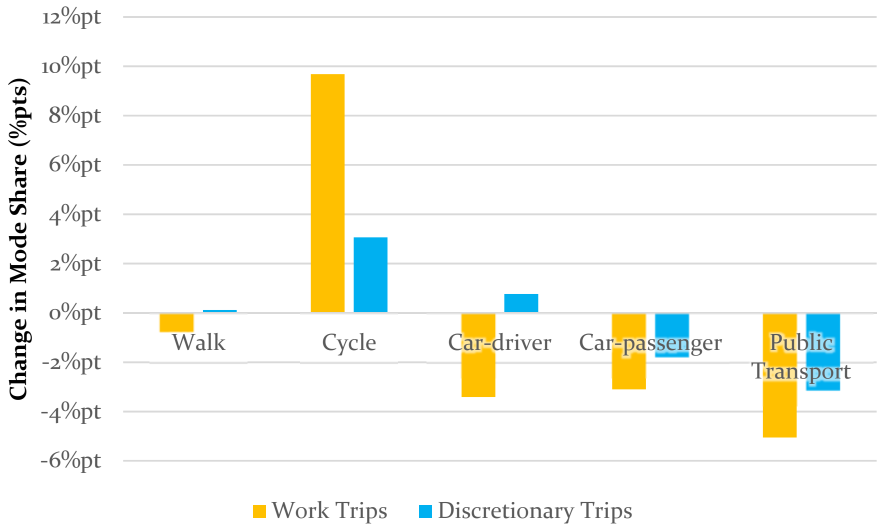

Figure 6.12 Shifts in mode shares of trips that cross the toll ring as the result of the 2010 scheme; source: Norwegian National Travel Survey of 2014

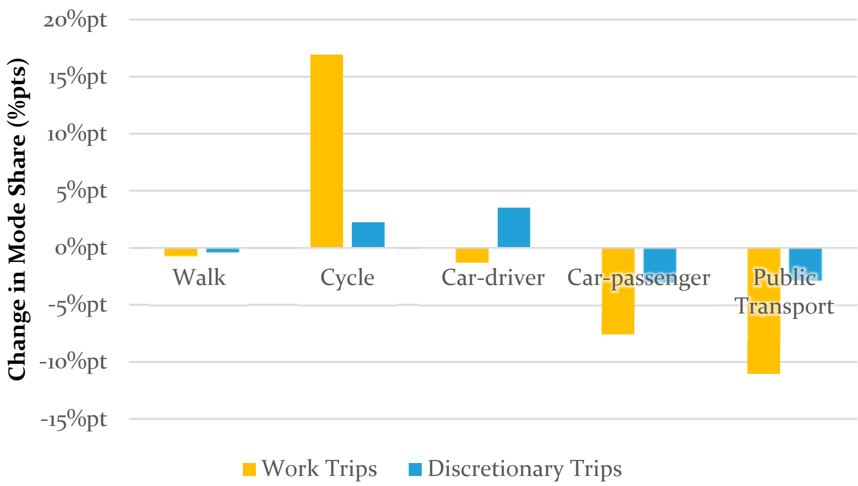

Figure 6.13 Shifts in mode shares of trips that cross the toll ring as the result of the 2014 toll scheme; source: Norwegian National Travel Survey of 2014

Table 6.2 shows the impacts of the 2010 toll scheme on frequency of the trips that cross the zones and the frequencies of trips within zones. A pronounced change from the corresponding impacts of the 2014 scheme is related to the trips that cross the zones (see Table 6.1). This figure in 2010 was 14 percent, and it increased to 26 percent in 2014. If the change were to be ascribed to the long-term impact of the 2010 the scheme, it should have been the opposite. A smaller percentage of the trips should have crossed the zones in 2014. The change is related to the increase in population and suburbanisation rather than the long-term impact of the 2010 scheme.

Table 6.2 Changes in trips frequency before and after the 2010 scheme; source: Norwegian National Travel Survey of 2014

Trips crossing the toll ring			
Period	**Total daily trips crossing the toll ring**	**All trips**	**Percentage**
Before	603	4282	14 %
After	694	5157	13 %
Internal trips in zone I			
Period	**Total number of trips within zone**	**All trips**	**Percentage**
Before	2826	4282	66 %
After	3403	5157	66 %
Internal trips in zone II			
Period	**Total number of trips within zone**	**All trips**	**Percentage**
Before	2152	4282	50 %
After	2458	5157	48 %

6.3 The Trondheim study of 2014

Results similar to those above emerge from a survey that was conducted in Trondheim in the spring of 2014. The main purpose of the Trondheim survey was to address research questions RQ 3.2 – RQ 3.6. The survey was conducted in the period of June 12 – July 14, 2014. The net respondents were 978 with a response rate of 20%. The survey was web-based and the respondents were recruited with email among a panel. The sample was weighted by gender, age, income, and the response rate by zones to represent the regional population.

About 39% of the respondents had their residence inside the toll ring that started operation in March 17, 2014 and about 61% lived outside the toll ring. We used the following structure in the design of the questionnaire:

1. Socio-economic data
2. Home & Work locations, changes in home & work locations since 2009 and reasons for changes

3. Car ownership, changes since 2009 and reasons for change
4. Travel behaviour and changes due to 2014 scheme
5. Working at distance and reasons

……

6. **Respondents' acceptance of the 2010 scheme (for, against, neutral)**
7. **Respondents' acceptance of the 2014 scheme (for, against, neutral)**
8. Reasons for their stands toward the 2010 and 2014 schemes
9. Respondents' acceptance of the scheme after outlining the objectives of the scheme
10. The respondents' preference for the type of scheme (time-differentiated vs. fixed tariffs)
11. Questions on respondents' attitudes on environment, transport policies, tax, equity, etc.
12. Respondents' travel habits
13. Perceptions of the traffic, parking, public transport service, environment, etc.
14. **How would you vote for the scheme today (for, against, neutral)**
15. How the scheme should be financed
16. Income and education

6.3.1 Changes in home and work locations

About 25% of the respondents had changed home location once and 19% had changed home more than once between 2009 and 2014 (see Figure 6.14). Only one of the respondents indicated that the scheme was at least one factor for the housing location decision.

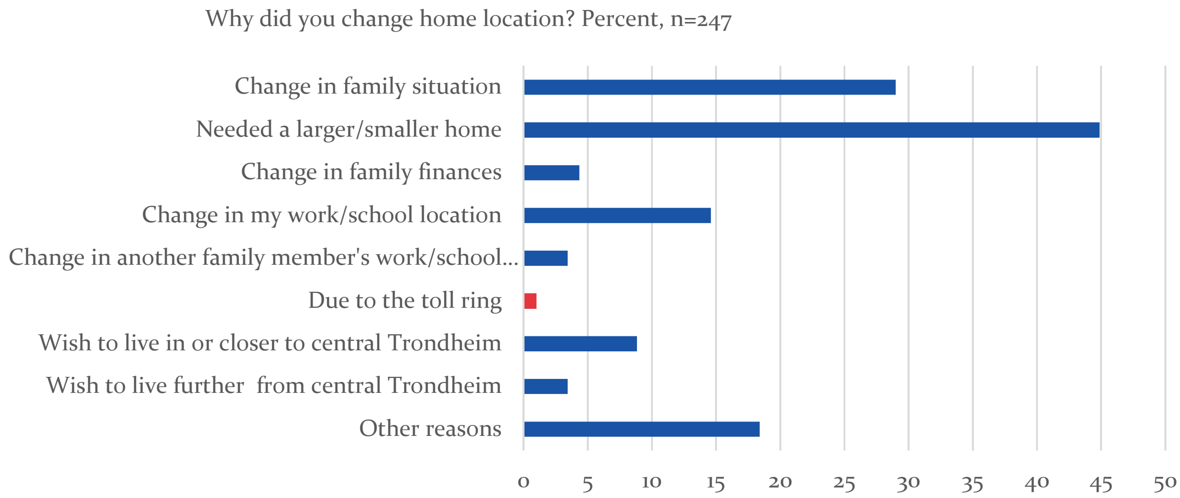

Figure 6.14 Changes in home and work locations; source: Public Opinion Survey of 2014

In a related question, 22% of the respondents indicated that they were *planning* to change their home location in the near future (see Figure 6.15). Ironically, 11% of the respondents indicated that the 2014 scheme is one reason for their plans. This is surprising since the transaction costs, monetary and non-monetary, involved in relocation of a home is much larger than the toll cost (see Ramjerdi 1994). This response could be an indication of their opposition to the scheme in 2014, rather than an actual change in home location because of the scheme.

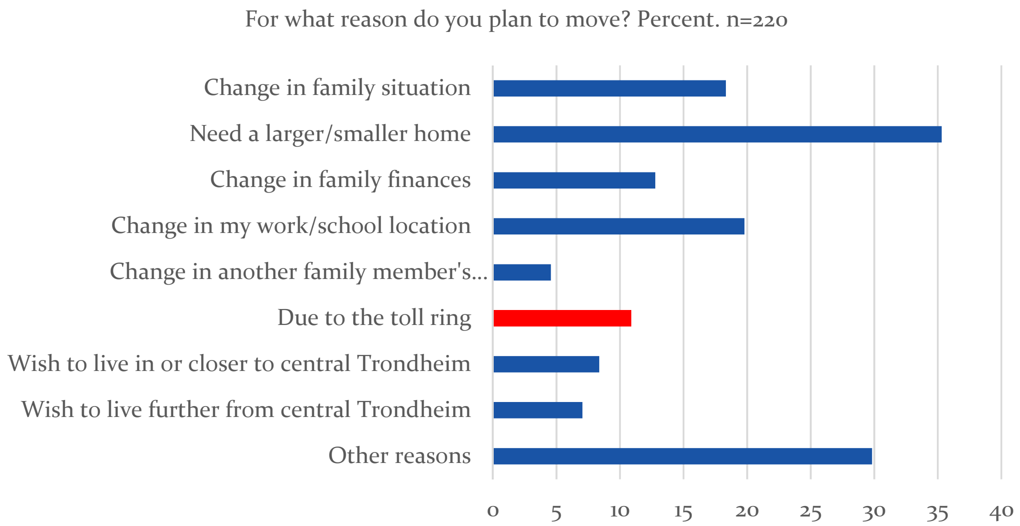

Figure 6.15 Reasons for planned changes in home location; source: Public Opinion Survey of 2014

About 43% of the respondents had changes in work location since 2009. Only 5% of the respondents indicated that the 2010 scheme was among the reasons for their change of work location. None of the respondents indicated that the 2010 scheme was the only reason for their decision. The corresponding figures for changes in work location are not presented here.

6.3.2 Change in car ownership

About 77% of the respondents had not changed the number of cars in their households, while about 16% had more cars and 7% had fewer cars in their household since 2009. The change in real toll fee since 2010 has been lower than the change in the average purchasing power in Norway. The change in real income is the most likely the expectation for the increase in car ownership in Trondheim.

6.3.3 Public acceptance of the 2010 and 2014 schemes

The original Trondheim toll scheme started operation in 1991. About 72% of the population was against the scheme before it started operation. Figure 6.16 shows public acceptance of the Trondheim toll schemes in 1992 and in 2005. The opposition to the scheme in 2005 was much higher than the opposition to scheme in 1992. The scheme had been modified and the toll fee increased between 1992 and 2005. However, the increase in real price of the toll fee was about 8% less than the change in real income. As seen in Oslo (see Section 3.5), it is likely that the resistance to a policy such as a toll scheme decreases over time, and yet the opposition is reignited when a discussion of a change arises. This phenomenon is referred to as cognitive dissonance that boils down to “accept the inevitable”.

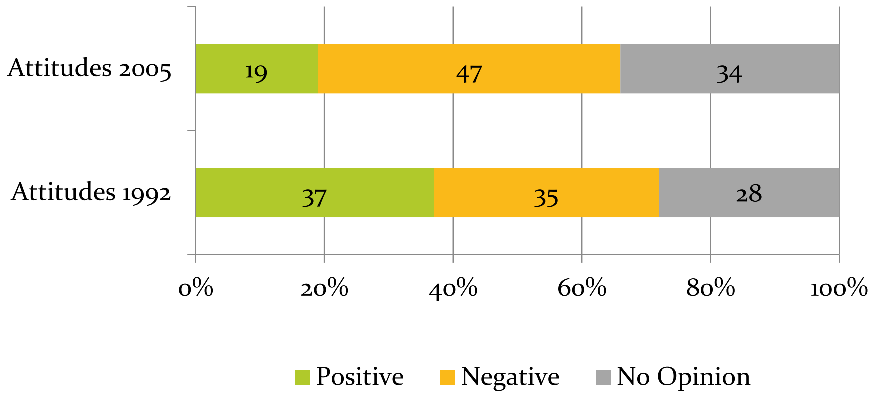

Figure 6.16 Attitudes to the toll ring in 1992 and 2005; source: J. Odeck and Welde (2010)

In the survey conducted in 2014, 56% of respondents stated that they were against the scheme in 2010, compared to 13% who supported the scheme and 31% who stated that they were indifferent. About 59% of the respondents stated that they were against the 2014 scheme, 12% supported the scheme and 29% were indifferent. The 2014 survey was conducted immediately after the introduction of the 2014 scheme, and opposition to the scheme then was larger than the opposition in 2005.

Figure 6.17 shows that the respondents were quite consistent in their opinions about the 2010 and 2014 schemes: very few respondents stated different views about the schemes in 2010 versus 2014.

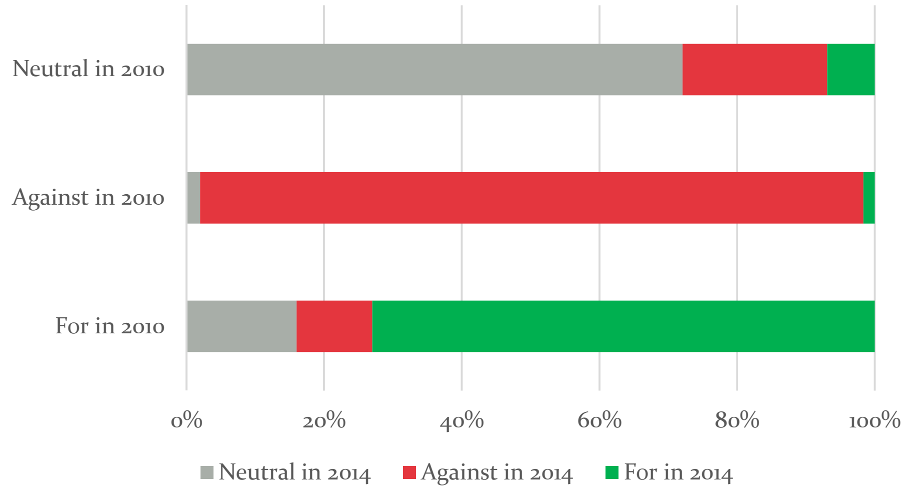

Figure 6.17 Change in support and opposition to the 2010 and 2014 toll schemes; source: Public Opinion Survey of 2014

Those who were positive towards the 2014 scheme rated the statements "It is fair way for the motorist to pay", "It contributes to better public transport" and "It contributes to better cycle paths and walkway" most highly; see Figure 6.18.

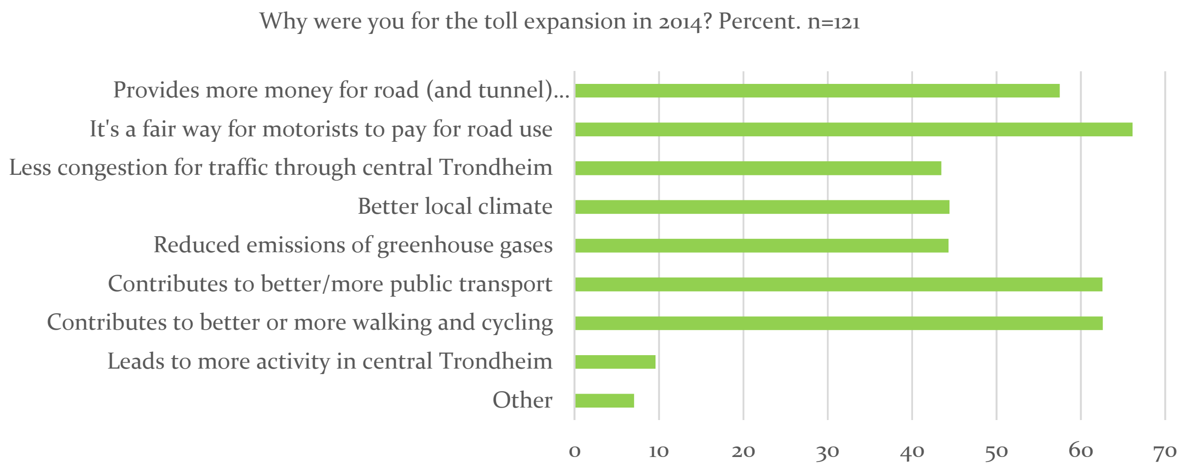

Figure 6.18 Attitudes related to support for the 2014 toll ring; source: Public Opinion Survey of 2014

Those who were opposed to the 2014 scheme agreed most with the statements “We already pay high taxes and fees”, “Authorities should pay for public transport, cycle and walking improvements” and “It reduces the activities in the centre”. See Figure 6.19.

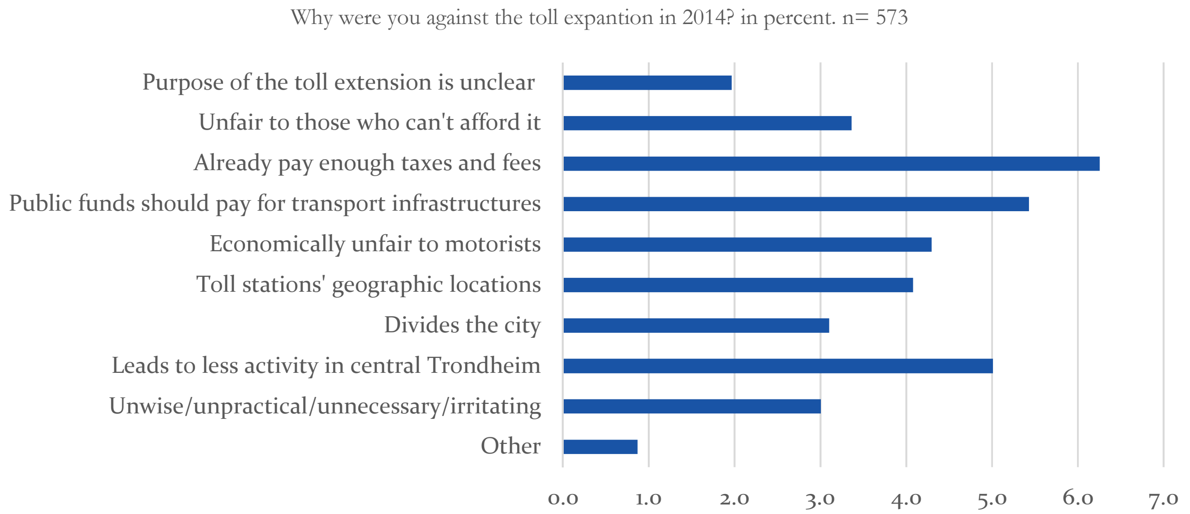

Figure 6.19 Attitudes related to opposition to the 2014 toll ring; source: Public Opinion Survey of 2014

The purpose of the 2014 scheme was stated as to improve public transport and traffic safety for cyclists and pedestrians, as well as to divert the through traffic and make improvements to the environment. Respondents were asked to state their opinions about the 2014 scheme based on the objectives of the scheme. Figure 6.20 shows their responses. The acceptance of the scheme increased compared to their earlier responses to the acceptance of the scheme.

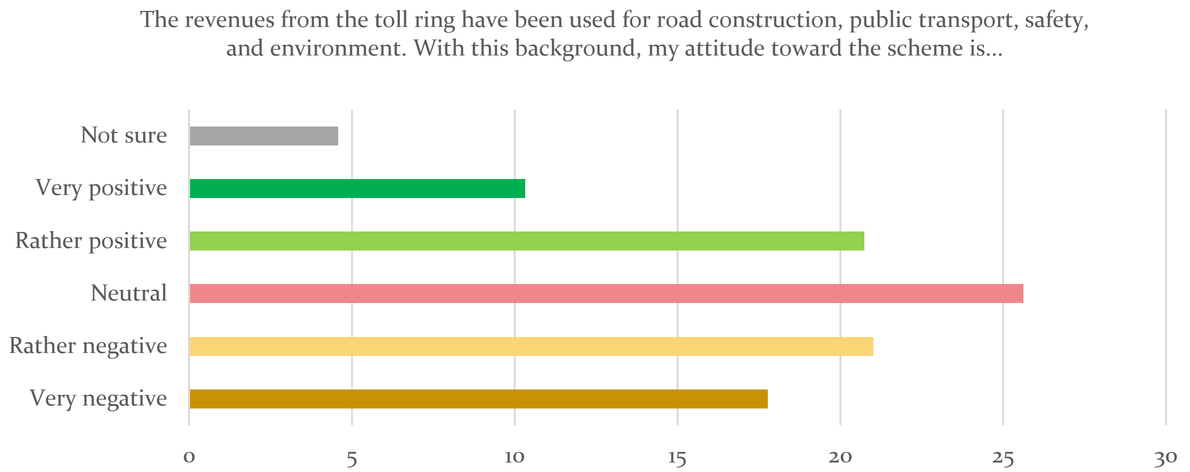

Figure 6.20 Opinions about the 2014 scheme with regard to its stated objectives; source: Public Opinion Survey of 2014

The subsequent questions related to the attitudes, habits, and perceived problems with traffic, public transport services and cycling and walking facilities in Trondheim. In Figure 6.21, we only present the respondents' beliefs related to driving a car. Most agreed with the statements "My driving a car has negative consequences for environment" and "It is important to do something about the pollution caused by driving a car". Less than 50% of the respondents agreed with the statement "May driving a car has negative impact on the health of others" and, while almost half of the respondents agreed with the statement "On principle, I have an obligation to drive less".

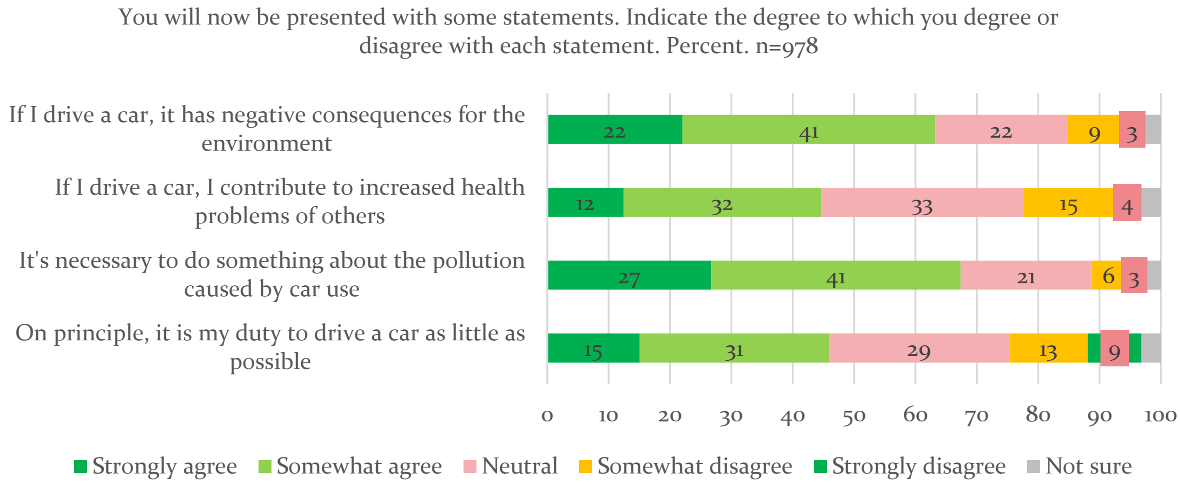

Figure 6.21 Attitudes related to driving a car; source: Public Opinion Survey of 2014

About 58% of respondents stated that public transport improvements made them more positive to the scheme. Almost 50% of the respondents believed that public transport services were improved.

These questions were followed by asking the respondents whether they would vote to keep or to abandon the scheme. As shown in Figure 6.21, about 53.5% of the respondents would vote for abandoning the scheme, 28.5% would vote for keeping the scheme and 18% were indifferent towards the scheme. These figures should be compared with the respondents' attitudes that were solicited earlier in the questionnaire. The corresponding figures were 61.4%, 13% and 25.5%. It seems that the statement of the scheme's objectives and the questions on their attitude, values and habits have made some of those who were earlier indifferent towards toll, now more supportive of the scheme. However, few respondents who were earlier for or against the scheme had now changed their opinion.

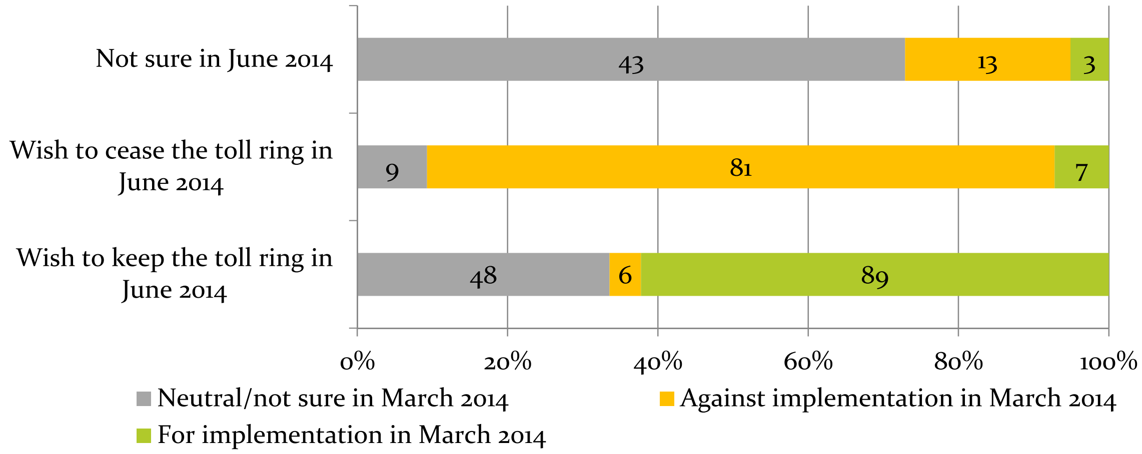

Figure 6.21 Changes in support and opposition to the 2014 toll schemes after statement of the objectives of the scheme, questions on value, attitude, habit, etc., of the respondents; source: Public Opinion Survey of 2014

6.3.4 Impacts on telecommunication

Less than half of the respondents (404 out of 978) have jobs that allow them to work at distance. About 29% of these respondents telecommute more than 2 days a week, 13% once a week, and 30% 1-3 times per month, while 28% seldom telecommute at all. About 18% of these respondents stated that avoiding toll payment was a reason for their telecommuting; other reasons for telecommuting were generally more important to these respondents. The respondents whose work category allows working at distance have higher income than the rest of population about 21% higher. It is plausible that these respondents have higher relative value for other factors than toll fees value for telecommuting.

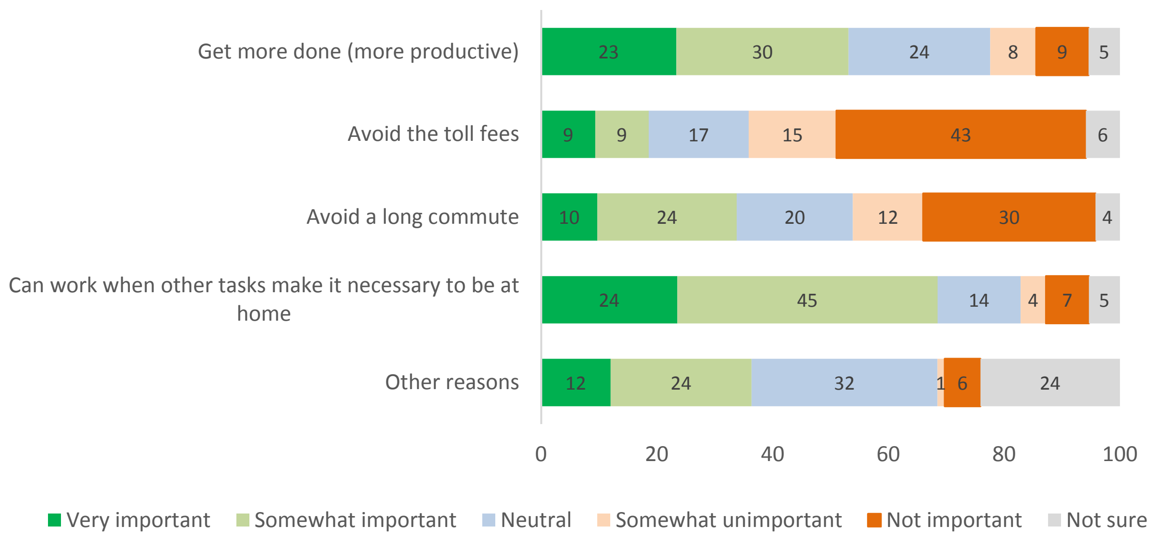

Figure 6.22 Attitudes related to teleworking; source: Public Opinion Survey of 2014

6.3.5 The impact of the type of scheme implemented (time-differentiated vs. fixed tariffs) on attitude

Most respondents supported a time-differentiated tariff. Only 30% of those who crossed a toll station stated that they would be more satisfied with a flat toll fee.

6.4 Review of Research Questions

RQ 3.1: To what extent do road tolls impact spatial and time distributions of travel in the short and medium term?

The response to this research question is based on two Norwegian National Travel Surveys that were conducted in the periods of September 2009 - September 2010 and September 2013 - September 2014 (see Section 6.2). A main shortcoming of these surveys is the number of respondents after the introduction of the schemes, which occurred in the second part of March. The seasonal change with profound effect on travel behaviour starts in mid-April. The data does not allow for a thorough separation of the impact of the schemes from seasonal effects on travel behaviour. To control for the impact of the seasonal change we have relied on changes in travel behaviour within zones inside and outside to the toll schemes. The impacts of the schemes on mode shifts and trip frequency seem negligible. This is in line with the evaluation of impacts of the scheme on travel behaviour in 1991 (Meland and Polak 1993). The locations of the toll stations in the 2014 scheme are similar to the scheme that was abandoned in 2005. The real increase in toll fee tracks with the increase in purchasing power in this period.

The analysis presented in this section shows that the medium- to long-term impact of the 2010 scheme has been negligible. The changes in home and work locations seem to follow the long-established trends in the pattern of land use, resulting in more trips crossing the “toll ring” in 2014, before the introduction of the 2014 scheme, than in 2010 after the introduction of the 2010 scheme.

RQ 3.2: Do people consider road tolls in decisions related to housing location, choice of school/kindergarten, and automobile ownership?

Sections 6.3.1 – 6.2.2 respond to these questions. The survey that was conducted in Trondheim in June and July 2014 shows that the 2010 scheme did not have an impact on changes in home location. Only 5% of the respondents indicated that the 2010 scheme was among the factors, but not the only factor, that contributed to their change of work locations.

Car ownership has increased since 2009. The increase in the real toll fee since 2010 has been less than the increase in average purchasing power in Norway. This change in real income, and most likely the expectation of the change in real income, is an explanation for the increase in car ownership in Trondheim. It is difficult to conclude that the 2010 scheme has had any impact on the pace of car ownership.

RQ 3.3: Have improvements in public transport reduced the perceived disadvantages of road tolls?

The impacts of improvements in public transport on public acceptance of the schemes were traced through different questions in the 2014 survey, addressing public acceptance of the 2010 and 2014 schemes. A set of modelling exercise (not reported here) shows that those who supported the 2010 and 2014 schemes (almost identical) did so in support of the environment and of cycling and public transport. Those who were against toll think thought that taxes were high in Norway and they already payed enough fees; they identified themselves largely as car users, among other explanatory variables.

After a statement of how toll revenue is allocated to different purposes, including public transport, soliciting respondents’ beliefs on impacts of car on environment and health, and how they approve of allocating toll revenue for public transport purposes, a sizable percentage of the respondents that had been neutral to the 2014 scheme stated they would vote to keep the scheme. A sizable percentage of the respondents that had been negative to the 2014 scheme also stated they would vote to keep the scheme. The results seem to imply that information about allocation of toll revenue to public transport purposes had increased the respondents’ acceptance of the scheme.

RQ 3.4: Do road tolls increase employees’ propensity to conduct ICT-based work from home?

About 18% of the respondents whose job categories allowed for telecommuting stated that avoiding toll payment was a reason for their telecommuting. These respondents had generally higher incomes than the others. It is likely that a high enough toll would increase the number of employees that would consider ICT-based work from home (see Section 6.3.4).

RQ 3.5: Are resident attitudes toward road tolls determined by the type of scheme implemented (time-differentiated vs. fixed tariffs)?

Most respondents seem not to change their acceptance of the scheme with a flat fee (see Section 6.3.5).

RQ 3.6: Do adaptation patterns and attitudes vary by households'/individuals' demographic background, household type, location, and other factors (e.g., car access, access to public transport, working hours, kindergarten use, etc.).

The analyses presented in Section 6.2 suggest that the differences in impacts of the toll based on gender, income groups and education level were not significant. The size of the data set did not allow for further analysis of the impacts on other types of the groupings, such as household types, location and access to public transport.

7 Equity, Attitudes, and Acceptability in Gothenburg (Work Package 4)

Jonas Eliasson and Maria Börjesson, CTS/KTH

This section summarizes results and conclusions from two scientific papers:

- *Börjesson, M, Eliasson, J., Hamilton, C. (2016) Why experience changes attitudes to congestion pricing: the case of Gothenburg.* Transportation Research A 85, 1-16.
- *Eliasson, J. (2016) Is congestion pricing fair? Consumer and citizen perspectives on equity effects.* CTS Working paper 2016:5. (*Submitted to Transport Policy.*)

Readers who are interested in the full details of the methodologies and results are referred to the original source papers; this summary focuses on the main conclusions and findings.

7.1 Background

The main obstacle for introducing congestion pricing is often public resistance. Suggestions to introduce congestion pricing in a city usually stir debates that can quickly turn emotional. However, several cities have experienced that public support for congestion pricing has increased substantially after a congestion pricing system has been introduced, e.g. London (Schade and Baum 2007), Stockholm (Eliasson 2014; Eliasson and Jonsson 2011), Trondheim, Bergen and Oslo in Norway (comparing attitudes before road pricing systems to shortly afterwards; in all cities, resistance has increased again when discussions about continuations have started) (Tretvik 2003), United States (Zmud 2008), and Milan (Ozer 2012); there is also some evidence for the phenomenon for Singapore (Gopinath Menon and Kian-Keong 2004). Several explanations for this phenomenon have been hypothesized, but so far there has been little conclusive evidence as to which of the potential explanations are the most important.

The introduction of congestion pricing in Gothenburg provided an opportunity to try to separate the factors influencing attitudes to congestion pricing, to determine their relative importance, and in particular explore what were the driving factors of the anticipated change in public opinion. To do this, two postal surveys were conducted in Gothenburg before and after the introduction of congestion charges in January 2013 (the first in November 2012 and the second in November 2013). The survey was an adaptation of a survey first developed and used in a Swedish-French-Finnish study (Hamilton et al. 2014; Souche et al. 2014). The surveys were sent to random samples of adult residents in relatively central part of the Gothenburg region (the municipalities of Göteborg, Mölndal, Partille and Öckerö, and the postal areas Mölnlycke and Landvetter in Härryda municipality), resulting in 1582 (2012) and 1426 (2013) useable responses per year with response rates of 40% and 38%, respectively. The samples are independent, i.e. this is not a panel study; disadvantages such as attrition, self-selection and anchoring were judged to be larger than potential advantages of a panel study. The relatively low response rate may bias the results in terms of opinion towards the measures we study. It has, however, presumably less impact on the effect of fundamental values and self-interest on the option of these measures, which is the key interest of the present study.

Just as in the cases cited above, public attitudes in Gothenburg did indeed become substantially more positive after the introduction. Respondents were asked “In a referendum about the congestion charges and the related infrastructure package, how would you vote?” with answers on a five-grade scale from “Definitely yes” to “Definitely no”. The question was about both the congestion charges and the infrastructure, since they are intimately linked to each other; without congestion pricing, the infrastructure package is unlikely, and the other way around. At the time of the first wave (November 2012), a referendum was discussed but no decision had been made. At the time of the second wave (November 2013), it had recently been decided to hold a referendum in September 2014. Hence, the question was not a hypothetical issue. The survey also contained questions about a range of other issues; in fact, the study was presented as a general survey related to traffic attitudes, not a focused congestion pricing study. Respondents were presented with statements such as “Taxes are too high” and “Much more resources should be spent on protecting the environment”, and asked to what extent they agreed on a 7-grade scale, from “completely disagree” (1) over “neutral” (4) to “completely agree” (7)”. Some of the statements concerned social and political issues that might be associated with congestion pricing, such as environment, taxation and social equity. Some of them concerned acceptability for pricing mechanisms in other contexts, such as differentiated air fares and taxing noise and emissions.

Table 7.1 Stated voting in a referendum about the congestion charges and the infrastructure package; source: the authors’ ExpAcc study in Gothenburg

Year	**Definitely yes**	**Probably yes**	**Don't know**	**Probably no**	**Definitely no**	**Support excl. "Don't know"**
2012	10%	19%	14%	24%	34%	33%
2013	19%	23%	16%	20%	22%	50%
Change	+9%	+4%	+2%	-4%	-12%	+17%

Almost a year after the introduction, public opinion had become much more positive. Excluding “don’t know”, the share of positive respondents had increased from 33% to 50%. Moreover, the positive respondents were more convinced while the negative respondents were less convinced on average: the share of yes-voters that would “definitely” vote yes had increased from a third to a half, while the share of no-voters that would “definitely” vote no had decreased from three fifths to half (see Table 7.1).

The question is what caused this change in attitudes. The explanation that first springs to mind is probably that the increase in support can be attributed to the benefits that appear in the form of traffic and congestion reductions. This seems to be the most common explanation among commentators for the change in opinion. Indeed, previous studies have established a strong link between support for congestion charges and belief in their effectiveness (see e.g. Eliasson and Jonsson 2011).

However, analysis of the attitudes in Stockholm has shown that *changes* in such beliefs can only explain a minor part of the attitude change in Stockholm; Figure 7.1 shows the actual development of support for the Stockholm charges compared to what can be explained by only beliefs in effects and self-interest variables (amount of tolls paid).

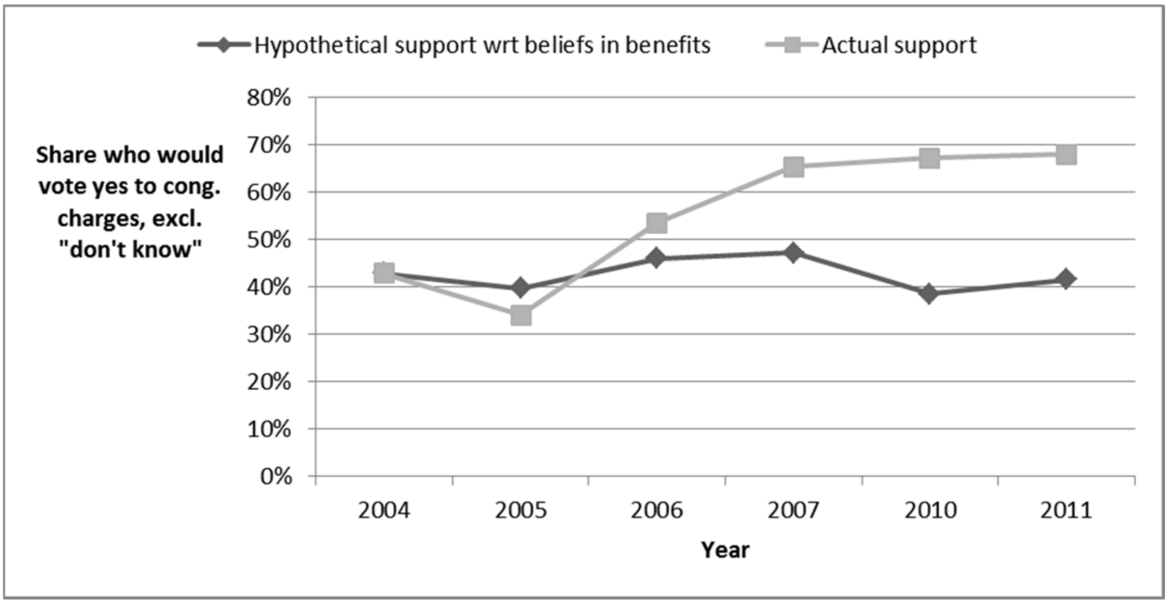

Figure 7.1 Stockholm: Actual support vs. hypothetical support if self-interest and beliefs in effectiveness were the only contributing variables; source: the authors' ExpAcc study in Gothenburg

Hence, it was expected that there were other contributing factors as well. The following possible contributing factors were hypothesized:

1. *Larger benefits than expected.* The support for charges after introduction may increase because benefits such as reduced congestion and improved urban environment turn out to be larger than expected. This is by far the most common explanation, put forward e.g. in a prescient paper by Goodwin (2006).

2. *Smaller downsides than expected*. Several authors have pointed out that adverse effects tend to be exaggerated before the introduction, and that resistance may decrease after introduction if problems such as increased public transport crowding and decreased inner-city retail turn out to be less serious than anticipated. In addition, adapting to the charges may seem more costly beforehand than it actually turns out to be (Eliasson 2008; Henriksson 2009).

3. *Benefits of accompanying measures*. Introduction of congestion charges is often accompanied by improvements in the transport system, for example in alternative modes or routes. These improvements are often paid for by (hypothecated) charge revenues, or at least marketed as part of a charges/infrastructure package. An increased satisfaction with e.g. the public transport system might spill over to an increased support for the charges. Several authors have argued that a "package approach" with accompanying measures is key for achieving acceptance for congestion pricing (Gopinath Menon and Kian-Keong 2004; Jones 1991).

4. *Changes in related attitudes.* Attitudes to congestion charges tend to be influenced by other related attitudes and values, such as environmental concerns, concerns for social equity, trust in government, and acceptability of general pricing principles such as user pricing, polluter pricing

and scarcity pricing (Eliasson and Jonsson 2011; Frey 2003; Hamilton et al. 2014; Raux and Souche 2004). The debates and campaigns surrounding the introduction of congestion charges may affect these other attitudes, which may then influence the attitude to congestion charges as a second-order effect. For example, it has been suggested that part of the increased support in Stockholm was caused by an increased acceptance for pricing policies in general (Börjesson et al. 2012).

5. *Reframing.* The strength with which various attitudes and values are associated with, and hence influence, the attitude to congestion charges may change over time, in particular if congestion charges are *reframed*, i.e. interpreted or marketed in a different way. For example, if congestion pricing is reframed from a fiscal policy to an environmental policy, it would be expected that the influence of self-interest and attitudes to taxation becomes relatively weaker compared to the influence of environmental concerns. How policies are framed often has a crucial effect on public support; Heberlein (2012) provides several examples.

6. *Loss aversion*. It is well established that losses are valued proportionally higher than gains in situations where there is a clear point of reference (Kahneman 2011). Hence, one might expect that increases in travel costs are valued higher before congestion pricing is introduced than afterwards, and improved travel times are valued higher after the introduction than before. Both phenomena would imply that car drivers would become more positive after the introduction than before. Note that this is different from benefits being larger (1) or adverse effects smaller (2) than expected; loss aversion refers to the phenomenon when effects are *valued* differently after a change, even when their *objective* size is undisputed.

7. *Status quo bias.* Status quo bias refers to situations when preferences for a policy are asymmetric – lower beforehand than afterwards. It may be caused by loss aversion, but can also be caused by cognitive dissonance (resistance tends to decrease if a change seems inescapable beforehand or irreversible afterwards) or resistance to changes as such, regardless of tangible losses or gains. Status quo bias of various kinds have been suggested to be one contributing factor to the increased support once congestion pricing is introduced (Brundell Freij, Jonsson, and Källström 2009; Eliasson 2014) or seems inevitable (Schade and Baum 2007).

7.2 Determinants of Attitudes to Congestion Charges

An earlier study (Hamilton et al. 2014) analysed determinants of attitudes to congestion pricing in three European cities – Stockholm, Helsinki and Lyon. The conclusions from that study were confirmed by the results from Gothenburg obtained in this study. The most important conclusions are, in summary:

- Self-interest matters. Respondents are more positive the higher value of time they have, the less they expect to pay, and the fewer cars they own. But self-interest is far from the only explanatory factor: it explains only a third of the total explained variation in Lyon and Stockholm, and around half in Helsinki and Gothenburg.
- Attitudes to congestion charges are strongly linked to various other attitudes. Three broad groups of such attitudes can be identified: environmental concerns, attitudes to public interventions, and attitudes to various kinds of pricing policies. Pricing policies can be subdivided into user pricing, polluter pricing and scarcity pricing, and the results indicate that higher acceptability for each of these pricing principles increase acceptability of congestion pricing.
- What issues are associated to congestion charges are in many respects similar in all the cities, but the strength of the associations varies. The strength of associations seem to depend on

how congestion charges are framed: in which specific local discourse it is placed, and how it is "branded" or "marketed". In some contexts, congestion pricing can be associated with environmental policies, in some contexts with fiscal policies, in some contexts with economic efficiency and so on.

Similar to the earlier study by Hamilton et al (2014), the Gothenburg study in this project estimated econometric models where respondents' attitudes to congestion charges are explained by their beliefs about the effects, self-interest variables (for example how much tolls they pay or expect to pay), and potentially related attitudes (e.g. environmental concerns). The surveys measured attitudes to a number of issues, hypothesized to be related to the attitude to congestion charges, by presenting respondents with statements and asking whether they agreed or disagreed on a 7-grade scale. Through the models, we can measure how much changes in attitudes and beliefs contribute to the change in the attitude to the charges, and hence test whether factors (1)-(4) in the list above contributed to the change in attitudes. By comparing models before and after the introduction of the charges, we could test factors (5)-(7). If reframing contributed to the attitude change (factor 5 on the list), the association between the congestion charging attitude and one or several of the attitude factors should change. If loss aversion contributed to the change (factor 6), then toll payments or time savings should be valued differently before and after the introduction, and hence affect the congestion charge attitude differently. The remaining, "inexplicable" change in attitudes to the charges can be attributed to status quo bias (factor 7).

The conclusions from Hamilton et al (2014) regarding which variables affected attitudes to congestion pricing were broadly confirmed by the Gothenburg analyses. Accepting pricing policies in general, environmental concerns and supporting public interventions all tended to increase support for the charges. Thinking that taxes in general and on cars in particular were too high, and that traffic was not a big environmental problem had a strong negative effect on the attitude to the charges. Attitudes to associated issues have a substantially higher influence on the support for congestion charges than self-interest. Attitude factors account for 79% of the explanatory power of the model, while self-interest variables account for 21% (however, a model with *only* self-interest variables can explain around half of the explained variation in the full model) and socio-economic variables for 0.2%.[12]

A common argument against congestion pricing is that it is inequitable – it hurts the poor disproportionally. If such concerns actually influence congestion pricing attitudes, we would expect to find a correlation between respondents' attitudes to social equity and their attitude to congestion charges. Respondents in all four cities were asked to what extent they agreed with the statement "*The government ought to do more to reduce the differences between the rich and the poor in society*". However, agreeing with this statement was *not* associated with a more negative attitude to congestion pricing in any of the cities; in Helsinki, it was actually associated with a more positive attitude. Hence, we find no correlation between concerns for social equity and resistance to congestion pricing. That equity effects is used as an argument against congestion charges may be because it is seen as a more morally valid argument than mere self-interest. In Gothenburg, this is perhaps particularly noteworthy, since low income groups actually pay substantially more in congestion charges, as a share of their income, than high-income groups do (see further below).

[12] A model with one constant only (applying to both years) has Log Likelihood (LL) -4735, adding the attitude variables increases the LL to – 4179, adding self-interest variables increases the LL further to -4031, and adding socio-economic variables increases the LL to -4031.

7.3 Explaining the Attitude Change

The explanatory factors of congestion pricing attitudes were hence no surprise – in most respects, Gothenburg attitudes were explained by the same factors as in the previous study of three other cities. The strengths of the various factors were also broadly similar.

The main question in this study, however, was what explained the *change* in attitudes. Some detailed econometric analysis yielded the following conclusions with respect to the potential explanations identified above:

1. *Larger benefits than expected?* Our results do not support this at all in Gothenburg. In fact, beliefs in positive effects actually *decreased* after the introduction.

2. *Smaller downsides than expected*? Beliefs in negative effects also decreased, on the other hand; the perception that things did not turn out as bad as expected may have contributed somewhat to the more positive attitudes. If we ignore reverse causality (that more positive attitudes may reduce beliefs in negative effects, rather than the other way around), decreased beliefs can have contributed with up to 9% of the total change in attitudes. Since there almost certainly is some degree of reverse causality, the real number is most likely lower than this.

3. *Benefits of accompanying measures*? Several improvements in the public transport system were made shortly before the introduction of the charges. They were partly funded by the revenues from the charges, and were marketed as a part of the general charge/infrastructure package. This hypothecation of charge revenues may have increased support for the charges. However, our analyses suggest that this contribution is almost negligible at 2%.

4. *Changes in related attitudes?* The process of introducing congestion charges and the associated debate and political campaigns may change related attitudes, for examples regarding environment, taxation or towards pricing policies in general. Our results lend some support to this; changes in related issues contribute with around 11% of the total change in attitude towards the charges. However, this change in related attitudes is not necessary caused by the introduction of the charges – it might simply be a part of longer trend in favour of the left/green political block, and this just happens to work in favour of the charges.

5. *Reframing?* A political debate or campaign charges can cause a reframing of the congestion charges, where the charges can be reinterpreted or "re-branded" from, say, a fiscal measure to an environmental measure. In the longer perspective, this is most likely an important mechanism, but there is no evidence of this in our results, which only span one year. All variables, including attitude factors, seem to influence the attitude towards the charges in exactly the same way before and after the introduction.

6. *Loss aversion*? Loss aversion in the strict sense does not seem to play a role. If it did, we would have seen a smaller attitude change among respondents who pay little or nothing compared to those how pay a lot. Instead, we see a similar change in attitudes across almost all groups, be it car drivers, environmentalists or public transport users, irrespective of self-interest and general attitudes.

7. *Status quo bias?* This is by far the most important mechanism, accounting for more than two thirds of the change. The status quo bias seems to be a general phenomenon: the change is resisted partly just because it is a change, and once the policy is there, the support increases partly just because "it's there".

7.4 Distributional Effects of Congestion Charges

Figure 7.2 shows the average charge payment for the Gothenburg toll scheme, as a share of income (in percent), per income group (SEK/month). Each income category is represented by its middle value (e.g. those who reported incomes from 15000-25000 SEK/month are shown at the point 20000 SEK/month). The black line is without taking company cars (which do not pay the charge) into account, while the blue take access to company cars into account. In both cases, the toll costs, as a share of income, decrease as income increases. On the other hand, even if low-income groups pay more charges relative to their income, they pay less in absolute terms, as seen in Figure 7.3.

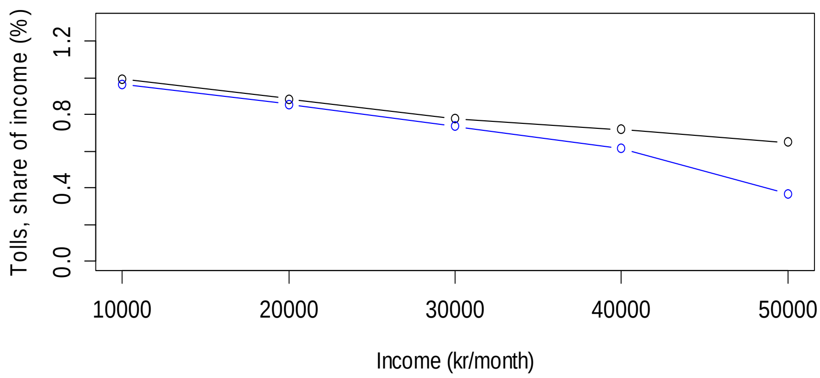

Figure 7.2 Average charges paid as a share of income (%), by income group (SEK/month); blue line takes into account company cars; source: the authors' ExpAcc study in Gothenburg

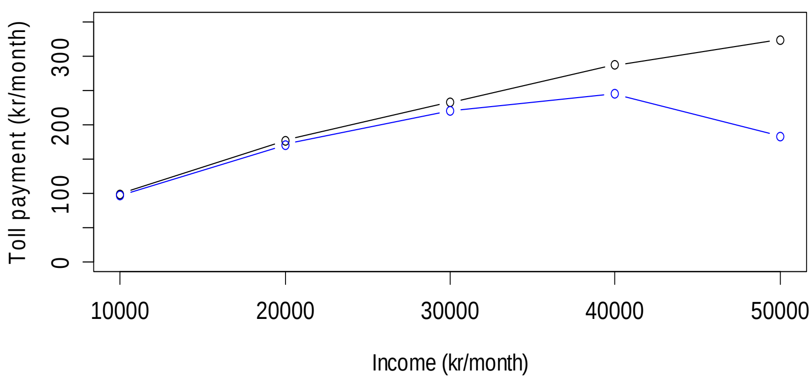

Figure 7.3 Average absolute charges paid (SEK/month), by income group (SEK/month); blue line takes into account company cars; source: the authors' Gothenburg ExpAcc study

It is not self-evident whether measuring toll payments in absolute terms of relative to income is the most relevant. If tolls are purely a fiscal measure, with the purpose to generate public revenues, then the share relative to income could reasonable be viewed as the most natural measure, since the alternative revenue source would most likely be income tax. But if tolls are a price correction – an adjustment to the cost of car driving to better reflect the full social cost of driving – then this is not so clear. Generally, prices are the same for everyone; monetary redistributions are taken care of by the public taxation and welfare system, and after that, prices are not different for different income groups.

The question is then to what extent the Gothenburg charges are a fiscal measure, and to what extent it is a price correction. It is clear that the charges have a dual purpose; but the weights given to the two purposes remain elusive. To the extent that it is a fiscal measure, the distributional profile is clearly regressive, especially when the fact that company cars are exempt is taken into account. The lowest income segment pays almost twice as much as percentage of their income than the highest income segment.

Besides income, there are other distributional dimensions, such as gender, age and so on. Figure 7.4 through Figure 7.6 show distributional profiles with regards to gender, age and education. As illustrated by the figures, there are no systematic differences in distributional effects across these dimensions, once income is controlled for.

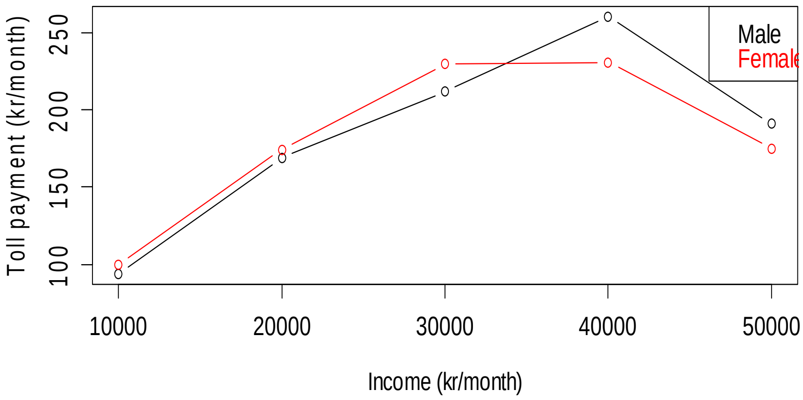

Figure 7.4 Average absolute charges paid (SEK/month), by income group (SEK/month), split by gender (black is male, red is female); source: the authors' Gothenburg ExpAcc study

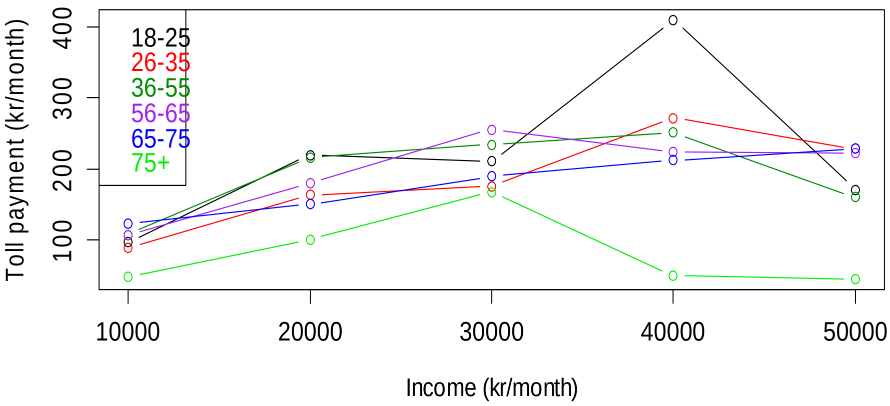

Figure 7.5 Average absolute charges paid (SEK/month), by income group (SEK/month), split by age group; source: the authors' Gothenburg ExpAcc study

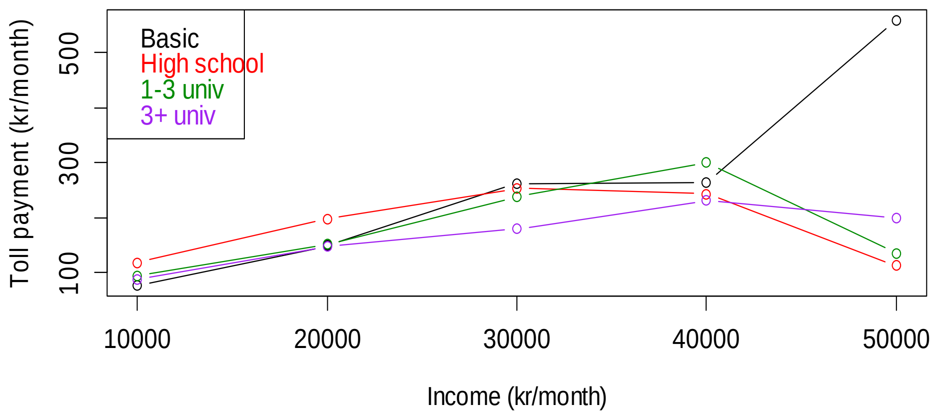

Figure 7.6 Average absolute charges paid (SEK/month), by income group (SEK/month), split by education level; source: the authors' Gothenburg ExpAcc study

Figure 7.7, however, shows that households with children pay considerably more than households without children, even after controlling for income. The difference is especially large for low-income households (the two lowest income groups).

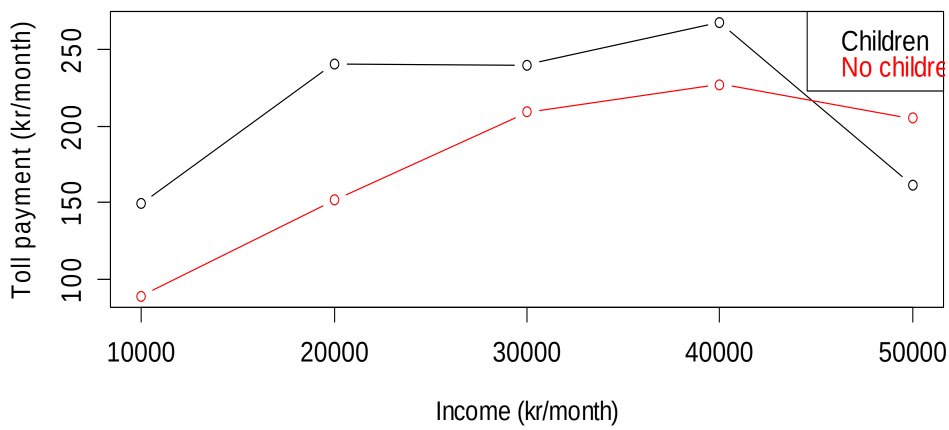

Figure 7.7 Average absolute charges paid (SEK/month), by income group (SEK/month), split by whether there are children in the household (under 21 years); source: the authors' ExpAcc study in Gothenburg

It should be pointed out that the distributional effects illustrated above only deal with toll payments. However, variables relating to self-interest—toll payments, car ownership, and value of time—only explain around half of the variation in attitudes to the congestion charges. The rest is explained by attitudes to environment, public interventions, and to pricing instruments in general. This means that there are many respondents who are "losers" according to the distributional analysis, but still would vote yes to the charges. Clearly, labelling such respondents "losers" seems strange. A more complete distributional analysis would take into account the notion that attitudes to congestion pricing are not determined by self-interest alone.

7.5 Review of Research Questions

In light of the above results, we are now ready to answer the research questions formulated in the original research proposal:

RQ 4.1: How do attitudes toward cordon tolls form over time, for the same individuals?

In Gothenburg, the same phenomenon was seen as in Stockholm and several other cities: as the introduction approached, attitudes became more negative, but once the charges were in place, attitudes became more positive.

The most important mechanism by far behind this was simply status quo bias—in other words, resistance to change in general. The existence of status quo bias poses a philosophical problem for democracies and welfare evaluation. If a population would vote against a policy before it is introduced, but would vote in favour of keeping it once it has been introduced, and the only reason for the change in attitudes is status quo bias—is it then democratically defensible to introduce the policy? One way to come to grips with this question is to say that it has to do with the characteristic of the policy: if it in some way means that resources are spent more efficiently, and if reasonable measures of public welfare increase, then one is tempted to answer yes. But this is far from an obvious answer; the question goes well beyond the scope of this project.

This project did not separately study attitudes to the infrastructure investment that the revenues from the charges are used for—in particular the major railway tunnel Västlänken – but only asked respondents how they would vote in a referendum about the congestion charges and the infrastructure investments as a package. However, analyses of other data sources indicate that the increase in negative attitudes to Västlänken was a major factor behind the majority voting against the congestion charges in the referendum in the autumn of 2014. This underlines that revenue use is also an important determinant of attitudes to congestion charges.

RQ 4.2: What general attitudes about fairness are static, and can any be influenced by experiencing an implemented toll cordon system?

Virtually all related social/political attitudes remained unchanged between the *before* and *after* surveys. In particular, the opinions about the various aspects of "fairness" remained stable. Contrary to expectations, concerns for social equity do not seem to be an important factor for explaining congestion pricing attitudes. The views of the fairness of pricing instruments, on the other hand—scarcity pricing, polluter pricing, and user pricing—play a very important role. In any case, neither of these attitudes changed, and neither did the influences or associations between the attitudes.

RQ 4.3: Do attitudes about fairness respond to information and communication campaigns in connection with urban policies such as cordon tolls?

As noted above, there were very little indications of such changes—except one: a year after the introduction, fewer agreed with the statement "Charges and taxes to own, park and drive a car are too high". The change is statistically significant. The change may be for several reasons: the communication in conjunction with the charges is one possibility. Other possibilities are reverse causality (if you become more positive to charges, that will tend to influence your other attitudes as well), or the general left/green political trend during the period when the studies were carried out which was evident from general political opinion polls.. We can only conclude that the information and communication campaigns may have had some influence on the views of what the "fair" costs of owning or using a car really are.

RQ 4.4: Are the patterns of general attitudes toward fairness universal, or do they vary considerably between different cities?

The *links* between fairness (including fairness of various pricing instruments) and attitudes to social equity are broadly similar in all the four cities where the ExpAcc survey has been carried out – Helsinki, Stockholm and Lyon (reported in Hamilton et al (2014)) and Gothenburg (analysed in this study). The *levels* of these attitudes are also similar between the cities, but there are some interesting differences. Table 7.2 shows the share of respondents agreeing (answer 5-7 on a 7-grade scale) with three statements regarding fairness.

Table 7.2 Share agreeing with statements (≥5 on 7-level scale); source: the authors' ExpAcc study

	Stock-holm	**Helsinki**	**Lyon**	**Gothen-burg (before)**	**Gothen-burg (after)**
"The government should prioritise to reduce the differences between the poor and the rich in the society."	57%	63%	73%	69%	71%
"It is reasonable that airplane tickets cost more for departure during peak hours than during off-peak"	52%	48%	37%	57%	56%
"It would be reasonable if the noisiest cars and motorcycles were subject to a special noise tax"	37%	36%	57%	38%	40%
"Taxes are too high in [country]"	54%	61%	67%	51%	45%

There are a few interesting differences across cities. More people in Gothenburg than in Stockholm agree that differences between rich and poor should be reduced. In this respect, Gothenburg is more similar to Lyon than to Stockholm or Helsinki. Compared to Lyon and Helsinki, both the Swedish cities show higher acceptance of a scarcity pricing instrument—peak pricing for air traffic—and higher acceptance for general tax levels. The table also shows how stable attitudes are in Gothenburg before and after the introduction of the charges.

The survey contained a question regarding how limited space on a car ferry should be allocated. Respondents were asked to grade four allocation mechanisms with respect to how "fair" they were: pricing, queuing, a public agency deciding which drivers have the most need to get on the ferry, or lottery. Table 7.3 shows the outcome.

Table 7.3. Share of respondents who perceived allocation strategies as "fair" and "unfair" (≥5 and ≤3 on 7-level scale); source: the authors' ExpAcc survey in Gothenburg, Hamilton et al (2014) in the other cities

	Stockholm		Helsinki		Lyon		Gothenburg before		Gothenburg after	
	Fair	**Unfair**	**Fair**	**Unfair**	**Fair**	**Unfair**	**Fair**	**Unfair**	**Fair**	**Unfair**
Price	68%	10%	63%	16%	51%	37%	66%	17%	67%	16%
Queue	59%	18%	79%	7%	23%	68%	66%	22%	65%	21%
Authority determines "need"	25%	43%	13%	68%	17%	73%	33%	48%	34%	44%
Lottery	7%	69%	9%	72%	7%	88%	8%	80%	9%	79%

Again, most answers are similar across cities, but there are some differences. In Lyon, many more view all the allocation mechanisms as "unfair". Again, attitudes are very stable in Gothenburg before and after the introduction of the charges.

RQ 4.5: Can differences in patterns of general attitudes be explained by specific features of the transport system and other aspects of implemented urban policy?

The transport system has a clear effect on the attitudes to congestion charges in several interdependent ways. First of all, paying more charges tends to decrease support (all else equal). Since a much large share of the population pay charges in Gothenburg than in Stockholm, and many more pay substantial amounts of charges (see Table 7.4), this is one factor explaining the lower support in Gothenburg. Obviously, this is associated with other factors which also affect support for the charges: the initial mode share of car vs. other modes, the average satisfaction with public transport, and the availability and attractiveness of alternatives to driving on charged links.

Table 7.4 Frequency of car trips past charging point during charged hours; source: the authors' ExpAcc study

How often do you pass a charging station by car during charged hours?				
	Almost every day	**A few times per week**	**A few times per month**	**Rarely or never**
Stockholm	8%	11%	26%	55%
Gothenburg	26%	19%	22%	32%

Figure 7.8 shows the level of support in different income groups (monthly income on the x-axis) for two groups: those who pay almost every day (black) and those who pay a few times per week (blue). Clearly, support in the group who pays every day is lower than in the other group (support in the groups who pay more seldom is even higher, although this is not shown in the figure). Interestingly, there is also a clear income effect: for a given average toll payment, support is higher the higher the income is.

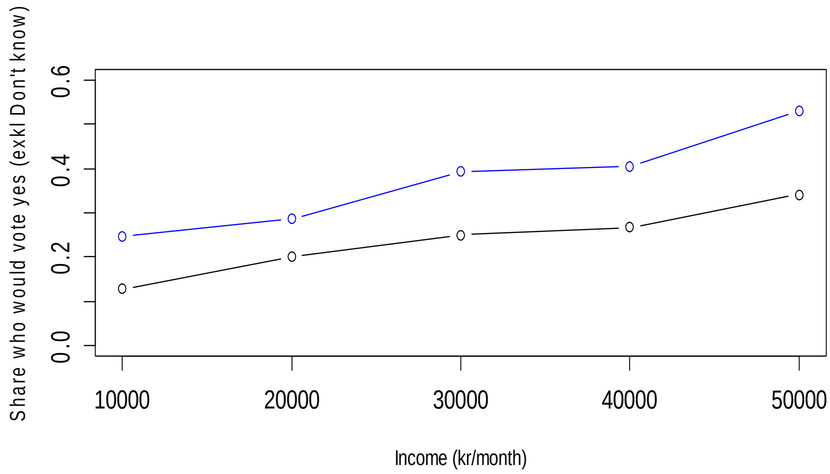

Figure 7.8 Support for charges (share) in Gothenburg by income group (SEK/month); daily payers in black, occasional payers in blue; source: the authors' ExpAcc study in Gothenburg

The corresponding results for Stockholm are shown in Figure 7.9. Here, the correlation between income, toll payments and support is weaker, although the same phenomenon is seen for the lowest income segment.

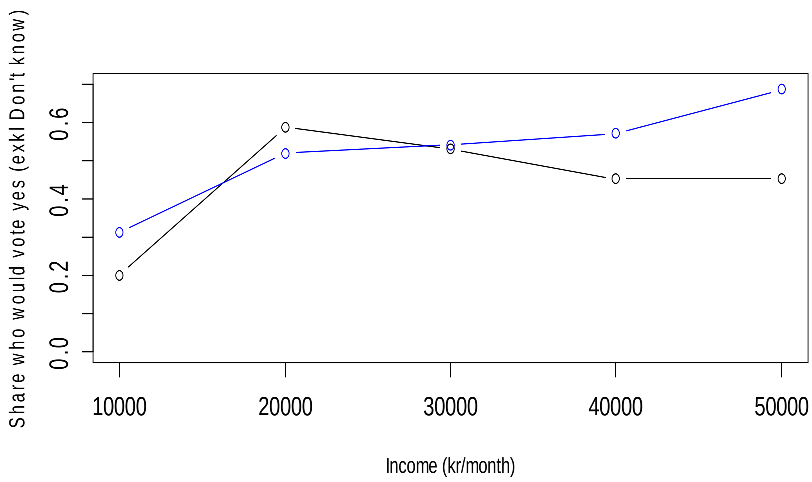

Figure 7.9 Support for charges (share) in Stockholm by income group (SEK/month); daily payers in black, occasional payers in blue; source: the authors' ExpAcc study in Gothenburg

At any rate, it is clear that both the transport system and the policy design affect public support. Generally, the fewer who pay, and the more attractive alternatives there are, the higher the support will tend to be.

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