The Gothenburg congestion charges: cost–benefit analysis and distribution effects

Jens West¹ · Maria Börjesson^{1,2}

Published online: 18 January 2018

© The Author(s) 2018. This article is an open access publication

Abstract This paper performs an ex-post cost–benefit and distribution analysis of the Gothenburg congestion charges introduced in 2013, based on observed effects and an ex-post evaluated transport model. Although Gothenburg is a small city with congestion limited to the highway junctions, the congestion charge scheme is socially beneficial, generating a net surplus of €20 million per year. From a financial perspective, the investment cost was repaid in slightly more than a year and, from a social surplus perspective, is repaid in < 4 years. Still, the sums that are redistributed in Gothenburg are substantially larger than the net benefit. In the distribution analysis we develop an alternative welfare rule, where the utility is translated to money by dividing the utility by the average marginal utility of money, thereby avoiding putting a higher weight on high-income people. The alternative welfare rule shows larger redistribution effects, because paying charges is more painful for low-income classes due to the higher marginal utility of money. Low-income citizens pay a larger share of their income because all income classes are highly car dependent in Gothenburg and workers in the highest income class have considerably higher access to company cars for private trips. No correlation was found between voting pattern and gains, losses or net gain.

Keywords Congestion charges · Cost–benefit analysis · Welfare analysis · Equity · Transport policy · Decision support

Introduction

Congestion pricing has proven to be an effective policy for reducing congestion and increasing welfare, but is still only implemented in a few cities: Singapore (Olszewski and Xie 2005; Phang and Toh 1997), London (Santos 2002; Santos and Shaffer 2004)

✉ Maria Börjesson
maria.borjesson@vti.se

¹ KTH Royal Institute of Technology, 100 44 Stockholm, Sweden

² VTI Swedish National Road and Transport Research Institute, VTI Box 55685, 102 15 Stockholm, Sweden

Stockholm (Börjesson et al. 2012; Eliasson 2009) and Milan (Carnovale and Gibson 2013). Gothenburg, located on the Swedish west coast, introduced a time-of-day dependent cordon-based congestion charging scheme in January 2013. This paper presents an ex-post welfare and distribution analysis of the Gothenburg system, and adds to the literature because it is by far the smallest city (half a million citizens) for which such effects have been evaluated. However, some small cities have implemented some form of congestion pricing (Durham; Santos (2004) and Minneapolis; Xie (2013)).

A number of theoretical studies examine welfare and distribution effects of congestion charges (Arnott et al. 1994; Evans 1992; Glazer and Niskanen 2000; Verhoef and Small 2004). They find that although congestion charges increase welfare, they are likely regressive in cities where driving patterns among low-income and high-income groups are more similar. A few studies also explore the welfare of real-world examples. Danielis et al. (2012) find a welfare effect of Milan's Ecopass system of €7–12 million per year. (Gibson and Carnovale 2015) show that the welfare benefits from reduced air pollution add nearly another €2.7 billion per year. Eliasson (2009) finds a net benefit of €70 million per year for the Stockholm charges, but the consumer surplus for drivers is still negative. Börjesson and Kristoffersson (2014), however, show that when including network effects (travel time savings further out in the network), intra-individual variation in the value of travel time (VTT), and reduced scheduling disutility, the consumer surplus of the Stockholm charges is in fact positive. Transport for London (Santos and Shaffer 2004) and Prud'homme and Bocarejo (2005) present different cost–benefit analyses of the London congestion charges based on observed traffic effects. The former study finds a net benefit of the charging system of approximately €70 million per year, whereas the latter finds a net loss of the same magnitude. The main difference between the two studies is, according to Mackie (2005), the method of calculating travel time savings and the Value of travel time (VTT); Prud'homme and Bocarejo do not consider travel time savings outside of the charging zone and apply a lower VTT.

There are also a few equity studies on real congestion charging systems: San Francisco (Schiller 1998), Oslo (Fridstrøm et al. 2000), Stockholm (Eliasson and Mattsson; 2006) and Cambridge, Northampton and Bedford (Santos and Rojey 2004). These studies indicate that high-income groups are affected the most since they drive more. However, analysing payments in four European cities, Eliasson (2016) concludes that congestion charges in all cities are regressive (i.e., that the total congestion charge relative to income decreases with increasing income).¹ Moreover, Levinson (2010) concludes that high-income groups in general benefit the most from HOT lanes. Ison and Rye (2005) and Rye et al. (2008) note that if not considering the use of the revenues, the (proposed) congestion charging systems in the UK (the London system and other suggested systems) and Singapore hurt low-income groups more.

In this paper we explore how the costs and benefits of the Gothenburg charges are distributed across different segments of the population distinguished by income, gender, age group, and zone (location) of residence. Virtually all previous studies on distribution effects have applied different values of time for different groups of travellers (see for instance Eliasson and Mattsson (2006), Verhoef and Small (2004) and Mayeres and Proost (2001)). However, these studies have disregarded whether the value of travel time differs between groups because of variation in the marginal utility of time or marginal utility of income, which we argue matters when exploring how the benefit of travel time gains is distributed in the population. If the value of time differs between income groups because

¹ Suits (1977) uses this definition of a regressive/progressive instrument.

high-income travellers have lower marginal utility of money, differentiating the values of time by income groups in a welfare/distribution analysis puts a higher weight on the travel time gains accruing to high-income travellers. This is the main argument of Galvez and Jara-Díaz (1998).

To avoid putting higher weights on high-income travellers in cost–benefit analyses (CBA), an often used solution is to apply the same average value of time for all income groups (Mackie et al. 2001). However, plenty of studies show that income differences explain a limited part of the variation in the values of time in the population (Börjesson and Eliasson 2012; Fosgerau 2007; Ramjerdi et al. 2010), presumably because the marginal utility of time varies in the population. In the distribution analysis in this paper we therefore use an alternative welfare rule, where the utility is translated to money by dividing the utility by the average marginal utility of money, thereby avoiding putting a higher weight on high-income people. We are still able to take into account the benefit of sorting of travellers between charged and un-charged routes (Verhoef and Small 2004). To explore the sensitivity of our assumptions, we also make the distribution analysis using the standard welfare measure and find that it shows larger redistribution effects.

In Gothenburg the congestion is limited to a few highway junctions and the share of public transport trips is comparatively low: 26% for commuting trips in the OD (origin–destination) pairs where the charges apply (Björklind et al. 2014). The corresponding market share in Stockholm was 77% in 2006 before the charges were implemented (SL 2013). Although the average charge per trip in Gothenburg is approximately half of what it is in Stockholm, the system generates approximately the same revenue. Hence, a substantially larger share of the population regularly pays the charge. In Stockholm, only a small share of the population pays the charge on a regular basis, and those who do generally have high incomes (80% of the commuters in the charged OD-pairs, and therefore most low income commuters, already used public transport before the charges were introduced or do not commute to and from the city centre). However, due to the higher car dependence among the commuters in Gothenburg, also many low-income citizens were and are still driving on the charged links, indicating that the Gothenburg system is more regressive than the Stockholm system.

Several authors have emphasized that the use of revenue should be taken into account to get a complete picture of the equity effects of a congestion charging system (Eliasson and Mattsson 2006; de Palma and Lindsey 2004; Santos and Rojey 2004; Small 1982, 1983). Ison and Rye (2005) argue that the preferred use of revenues is for local public transport for equity reasons. This is also the case in London, where the revenues from the charging system are spent on local public transport. In Gothenburg the revenues co-finance a package of investments (West Swedish Agreement, October 28, 2009). The largest investment in the package is the West Link (€2.0 billion), which is an 8-km-long rail link including a 6-km-long tunnel under central Gothenburg. Most of the benefits of the West Link will accrue to individuals residing close to train stations far out in the greater Gothenburg region, and not primarily to the travellers affected by the charging system. The tunnel has also very low value for money (BCR 0.45 (Mellin et al. 2011)). Moreover, had the congestion charges not been financing the tunnel, they would never have been implemented and the tunnel would not have been built (West Swedish Agreement, October 28, 2009). For these reasons we have not considered the recycling of money in our welfare measure as Mayeres and Proost (2001) do.

Levinson (2010) and Ison and Rye (2005) underscore that the distribution of costs and benefits of a charging system depends on the design of the system, including for instance exemptions and discounts. This is demonstrated by the Swedish congestion charging systems, where the congestion charge for private trips is included in the “taxable benefit

value” of company cars. To avoid this, most employers also pay the congestion charges for company cars for private trips. This implies negative effects on equity, since most company car users belong to the highest income segment.

Levinson argues that public opinion depends on the distribution (and the public’s perception of the distribution) of the gains and losses of a (proposed) charging system. The Gothenburg system has indeed low public support: a consultative referendum was held in September 2014, where fifty-seven per cent voted against the charges, although the support had increased since introduction of the charges in January 2013. The reason for keeping the charges is related to the co-financing of some large infrastructure investments in the region (see further “[The Gothenburg congestion charges](#)” section).

The paper is organized as follows. “[The Gothenburg congestion charges](#)” section describes the charging system, “[Cost benefit analysis](#)” section the CBA methodology, and “[Result: CBA](#)” section the CBA results. The method and results of the equity analysis are included in “[Distribution of the gains and losses](#)” section and “[Conclusions](#)” section concludes.

The Gothenburg congestion charges

Gothenburg (Göteborg in Swedish) is the second largest city in Sweden with half a million inhabitants within the city and nearly a million in the larger metropolitan area. The city is traditionally a seaport and manufacturing city dominated by blue-collar jobs, the car manufacturing industry being one of the dominant sectors. The blue-collar jobs are mainly located north of the Göta River, while the central business district is located south of it. Gothenburg is a sparsely populated metropolitan area. Its spatial pattern of development does not support an efficient public transport system, implying a considerably lower share of public transport than in Stockholm.

Gothenburg has begun its shift towards a more high-tech and service-oriented economy. The population in the city of Gothenburg was relatively stable during the second half of the 20th century, but since the beginning of the 21st century it has increased by 17%, which has increased the population density. The city communicates a planning strategy leading to a denser and more transit-oriented city, for instance it aims for a doubling of the public transport market share from 2006 to 2020.

A cordon-based congestion charging scheme was introduced in Gothenburg in January 2013 (see Fig. 1). The charge is time-of-day dependent, ranging from €0.8² to €1.8 during weekdays 6.00–18:30, while other time periods are free of charge. A multi-passage rule applies which states that drivers only have to pay once when passing the cordon more than once during 60 min. The maximum daily charge is €6. Vehicles are charged when passing the cordon in either direction using automatic number plate recognition. The main objective of introducing congestion charges was to raise a yearly revenue of €100 million to co-finance a large infrastructure package, mainly a rail tunnel. Other objectives were to reduce congestion and improve the local environment. Congestion in Gothenburg was, however, mainly concentrated in the highway hub depicted in Fig. 1.

Up until 2015, the average charge was approximately €0.5 per passage (accounting for the multi-passage rule), compared to €1 for the Stockholm system.³ In 2013 the number of

² Here and in the rest of this paper we use the conversion rate 10SEK = €1.

³ From January 2015, the peak hour charge was increased from €1.8 to €2.2 in Gothenburg and from January 2016 from €2 to €3.5 in Stockholm. For a description of the effects of the increase and extension of the charge see Börjesson and Kristoffersson (2017).

Fig. 1 Gothenburg with the toll cordon depicted in red, main roads in black and highway hub in blue. (Color figure online)

passages was 132 million and the total revenue €71 million in Gothenburg to be compared with 78 million passages and the total revenue of €76 million in Stockholm. Since Gothenburg is less than half the size of Stockholm, each citizen thus pays on average twice as much as in Stockholm.

Public resistance against the congestion charges resulted in a consultative referendum in conjunction with the regularly-scheduled general election to the national parliament and to the city council, held on 14 September 2014. The referendum question was formulated as: “Do you think that the congestion tax should continue after the 2014 election?”. Fifty-seven per cent of the voters in the municipality voted “No”.

Now, the key factor for receiving political support for charges was an agreement with the national government that Gothenburg would receive a major infrastructure package, funded by the congestion charging revenue, leveraged with an equally large national grant. Since a large share of the revenue from the charges is collected from citizens in surrounding municipalities, the agreement is a favourable deal for the city of Gothenburg, with all established political parties supporting the agreement. Since no alternative sources of funding could be found the congestion charges were kept.

Cost–benefit analysis

In the design phase, the traffic effects of the Gothenburg charges were forecast using the Swedish national transport model system Sampers. The traffic volume across the cordon and other major links in Gothenburg was observed before and after the introduction of congestion charges. Travel times were measured by cameras before and after the introduction of congestion charges (City of Gothenburg 2013b) on all major links in Gothenburg.

The effects in terms of traffic volumes and travel times simulated by the model correspond well to the observed effects (West et al. 2016). The observed reduction in traffic volume across the cordon was on average ten per cent⁴ while the model predicted nine per cent. On the links where the charges reduced travel times the most, (the arterials leading into and from the bottlenecks on the highway hub depicted in Fig. 1) the observed average travel time reduction was nine per cent while the predicted was eleven per cent.

The static assignment model predicted travel time effects of the congestion charges in Gothenburg with high accuracy because in Gothenburg there are few spill-back queues. Welfare effects should be computed at the OD-pair level rather than on link level to include secondary effects on competing routes (Neuburger 1971). Still, travel times and traffic volumes are observed on the link level and not on the OD-level. For this reason, we calculate of the consumer surplus on the OD-level based on output from the transport model but we calibrate the model carefully to match the observed traffic volumes and travel times on the link level. We calibrated both against the initial traffic volumes and travel times but also, more importantly, against *the effect* on them (by adjusting the value of time distribution as explained in “[Model description](#)” section). Hence, the model simulated effects on the travel times and volumes on the OD-level are consistent with the observed flows on links and travel times.

This methodology could not be applied in the CBA for the Stockholm congestion charges, because in Stockholm much of the congestion is dynamic, including spill-back queues and blocking of upstream intersections. The travel time reductions on links outside the cordon were therefore substantially underestimated by the transport model (Börjesson and Kristoffersson 2014; Eliasson et al. 2013).⁵

Model description

The national transport forecasting model Sampers consists of five regional models, where Gothenburg is covered by the western Sweden sub-model. The demand model consists of nested logit models for six trip purposes (work, school, business, recreation, social and others) covering trip generation, destination choice and mode choice, and are estimated on national travel survey data 1994–2001. The demand models are linked to the software package Emme/3, assigning demand by mode to the transport network, consisting of arterials and most streets. Smaller roads inside the zones are not explicitly modelled: the transport model assumes that all trips depart from and arrive at a given point within each zone, which is connected to the road network. For cars, travel times and cost from the assignment are fed back to the demand level in an iterative loop until convergence is

⁴ These figures are for the whole day—24 h—including non-charged hours.

⁵ The model-simulated travel-time reduction on the links crossing the cordon was, however, close to the observed.

reached, usually after the fourth iteration. Travel time and cost for public transport, walking and biking are assumed to be independent of transport volumes.

The OD matrices for freight and professional traffic are generated by a separate model, under the assumption that trip frequency, mode and destination choice of this traffic is insensitive to the charges. The route choice of the freight and professional traffic is, however, modelled in the assignment.

Since the transport model is static, the departure time choice is not modelled. Instead, the mode-specific OD matrices produced by the demand models are split into three time periods (morning peak, afternoon peak and off-peak) according to purpose-specific fixed factors. The OD matrices for each time period are then assigned to the network. The time-of-day dependent charge is approximated by a constant charge within each time period. The constant charge is computed as a weighted average across each 15-min interval within the given time period, the weights being the observed traffic volume. The approximation errors are highest for the off-peak period (e.g., midday when the charge ranges from €0.8 to €1.3 and night time which is free of charge).

EMME/3 distributes drivers by routes according to Wardrop user equilibrium. Path disutility U is assumed to be a linear function of travel time (T), travel distance (D) and congestion charge (C)

$$U = \alpha T + \beta D + C, \quad (1)$$

with α being the VTT and β the distance cost. The VTT α (of the drivers in each OD pair) is taken to be a random variable X following the log-normal distribution $\ln \mathcal{N}$. The parameter β is assumed to be equal across the population. In a standard network assignment, the path disutility (such as (1)) is assumed to be the sum of the disutilities of all links within the route. This assumption is valid for most transport networks. It is, however, not valid for the Gothenburg network where a multi-passarge rule applies: A driver only has to pay one charge even if he or she uses a charged link more than once within 1 h.

To implement the multi-passarge rule, a hierarchical route choice algorithm with two levels is applied in the assignment (West et al. 2016). In the upper level, the drivers are split into two classes, paying and non-paying drivers. In the lower level, the drivers are assigned to the network; the paying drivers have access to the complete road network while the non-paying drivers can use only the uncharged links.

The assignment is run iteratively. In the first step (the lower level of the route choice algorithm), the travel time T and travel distance D of each OD pair, for the paying and non-paying drivers, respectively, are calculated under the assumption that the drivers minimize the path disutility defined by

$$U = \tilde{\alpha} T + \beta D, \quad (2)$$

where $\tilde{\alpha}$ is the median VTT and β the average driving cost per kilometre. The route choice differs between paying and non-paying drivers because the former may use the complete road network while the latter may use uncharged links only. The charge C is set to zero in the lower level since the upper level of the route algorithm determines the share of drivers that pay the charge. Hence, only the relative weights of T and D , that is the ratio $\tilde{\alpha}/\beta$, determine the route choice. We use the median VTT $\tilde{\alpha}$, and not the VTT distribution, in this step in order to produce a unique travel time and travel distance for each OD pair. Unique travel times and travel distances are required in the upper level of the route choice. The travel-time and travel-distance matrices for the paying drivers obtained by network shortest

path skimming after the assignment are denoted T^p and D^p . For non-paying drivers, the corresponding matrices are denoted T^n and D^n .

The second step (the upper level of the route choice) determines the share of paying drivers in each OD pair. The random distribution of α implies that some drivers in the OD pair are better off paying a charge to save time, while others are not. A driver in OD pair (o, d) with VTT α^* is better off paying the charge C and choosing the faster route if $\alpha^* T_{o,d}^p + \beta D_{o,d}^p + C < \alpha^* T_{o,d}^n + \beta D_{o,d}^n$. The driver with the trade-off value of time, $k_{o,d}$, will be indifferent to paying the charge or to choosing a detour. This trade-off value is

$$k_{o,d} = \frac{C + \beta D_{o,d}^p - \beta D_{o,d}^n}{T_{o,d}^n - T_{o,d}^p}. \quad (3)$$

The share of paying drivers in each OD pair is

$$q_{o,d} = P(X > k_{o,d}) = \int_{k_{o,d}}^{\infty} \ln \mathcal{N}(\xi; \ln \tilde{\alpha}, \sigma) d\xi. \quad (4)$$

In the third step, the paying and non-paying drivers are assigned to the network simultaneously. The iteration is then repeated from the first step until convergence is reached. Since different trip purposes have different VTT distributions, the calculations (3) and (4) are done by trip purpose, but this is left out to simplify the notation.

The parameters $\ln \tilde{\alpha}$ and σ of the VTT distributions are taken from the Swedish VTT study (Börjesson and Eliasson 2014). For commuting trips, the median value of time, $\tilde{\alpha}$, is 5.1 €/h and the mean value of time, $\bar{\alpha}$, is 10.8 €/h. For business and freight trips, the median VTT is 27.3 €/h and the mean VTT 29.1 €/h, and for other private trips, the median VTT is 2.5 €/h and the mean VTT 4.9 €/h. However, the VTT distributions applied in the route choice are stretched to the right (i.e., $\ln \tilde{\alpha}$ is increased) compared to the distributions from the national VTT study (for instance, the stretched VTT for commuting trips has median 10.2 €/h). If the VTT distribution is not stretched to the right, the reduction of the volumes on the charged links is overestimated by the model (because the model over-predicts the number of drivers taking a detour to avoid paying the charge.).

We underscore that there is no strong reason to believe that the stretched VTT distribution represents the drivers' true VTT. One possibility is that the stretching of the VTT distribution controls for deficiencies in the coding of the network (such that the travel times on small roads and streets are underestimated in the model). Another possibility is that the route choice is influenced by attributes not represented in the network model that are correlating with travel time, such as the preference for larger arterials rather than smaller streets due to comfort, for instance. For this reason, we apply the original, not stretched, value of time distribution by trip purpose in the welfare calculation in “Consumer surplus” section. If, however, the stretched distribution accurately describes the value of time, the welfare analysis underestimates the benefits of the charges.

Consumer surplus

In this section the consumer surplus is derived. The consumer surplus depends on the paid charges, the travel time gains, the changes in driving costs, and the adaptation cost for drivers priced off the road. Benefits from reduced travel time variability are not included in the transport model but are assessed separately from camera data measuring travel times (see “Travel time variability” section). Welfare losses for public transport users due to

more crowding are approximated to zero for the reasons stated in “Public transport” section.

For drivers in OD pairs without the choice between an uncharged and a charged route alternative, the value of the changes in travel time is computed as

$$\Delta v_{o,d} = \bar{\alpha} (T_{o,d}^0 - T_{o,d}^1), \quad (5)$$

where $\bar{\alpha}$ is the mean VTT, and $T_{o,d}^1$ and $T_{o,d}^0$ are the travel times in the situation with and without congestion charges, respectively. The mean VTT is assumed to be constant across OD pairs.

For OD pairs where there is a choice between a charged and an uncharged route, the value of the travel time gain is calculated as

$$\Delta v_{o,d} = \bar{\alpha} T_{o,d}^0 - \left((1 - q_{o,d}) \alpha_{o,d}^n T_{o,d}^{1n} + q_{o,d} \alpha_{o,d}^p T_{o,d}^{1p} \right), \quad (6)$$

where $\alpha_{o,d}^n$ is the mean VTT for the non-paying drivers, $\alpha_{o,d}^p$ is the mean VTT for the paying drivers, and $T_{o,d}^{1n}$ and $T_{o,d}^{1p}$ are the travel times for paying and non-paying drivers in the situation with charges.

The mean VTT for paying drivers is

$$\alpha_{o,d}^p = E[X|X > k_{o,d}] = \frac{g_{o,d}}{q_{o,d}}, \quad (7)$$

where $g_{o,d}$ is the partial expectation with respect to $k_{o,d}$ for the log-normal random variable, defined as

$$\begin{aligned} g_{o,d} &= \alpha_{o,d}^p q_{o,d} = E[X|X > k_{o,d}] P(X > k_{o,d}) = \int_{k_{o,d}}^{\infty} \xi \ln \mathcal{N}(\xi; \ln \tilde{\alpha}, \sigma^2) d\xi \\ &= \bar{\alpha} \Phi \left(\frac{\ln \tilde{\alpha} + \sigma^2 - \ln k_{o,d}}{\sigma} \right). \end{aligned} \quad (8)$$

Here Φ is the standard normal cumulative distribution function. The derivation of the VTT expectation for non-paying drivers is straightforward since $\bar{\alpha} = (1 - q_{o,d}) \alpha_{o,d}^n + q_{o,d} \alpha_{o,d}^p$:

$$\alpha_{o,d}^n = \frac{\bar{\alpha} - q_{o,d} \alpha_{o,d}^p}{1 - q_{o,d}} = \frac{\bar{\alpha} - g_{o,d}}{1 - q_{o,d}}. \quad (9)$$

Combining (7) and (9) with (6) we have

$$\Delta v_{o,d} = \bar{\alpha} T_{o,d}^0 - \left((\bar{\alpha} - g_{o,d}) T_{o,d}^{1n} + g_{o,d} T_{o,d}^{1p} \right). \quad (10)$$

Note that for OD pairs where there is no choice between charged and non-charged routes, $g_{o,d} = 0$ and (10) collapses to (5).

The consumer surplus is

$$\Delta W = \frac{1}{2} \sum_{o \in O} \sum_{d \in D} (s_{o,d}^0 + s_{o,d}^1) (\Delta v_{o,d} + \Delta b_{o,d} - c_{o,d}), \quad (11)$$

where $s_{o,d}^0$ and $s_{o,d}^1$ are the OD-pair specific demand before and after the introduction of congestion charges, $\Delta v_{o,d}$ is the value of the change in travel time, $\Delta b_{o,d} = \beta \left(D_{o,d}^0 - \left((1 - q_{o,d}) D_{o,d}^{ln} + q_{o,d} D_{o,d}^{lp} \right) \right)$ is the change in driving cost, and $c_{o,d} = q_{o,d} C$ is the paid congestion charge per trip. If the average values of time $\alpha_{o,d}^p$ and $\alpha_{o,d}^n$ differ due to differences in the marginal utility of money arising from income differences, the welfare measure (11) implies that we put a higher weight on the travel time saving for high-income travellers; this is formally explained in “[Distribution of the gains and losses](#)” section.

The consumer surplus (11) can be rewritten as

$$\Delta W = \sum_{o \in O} \sum_{d \in D} s_{o,d}^1 (\Delta v_{o,d} + \Delta b_{o,d} - c_{o,d}) - \frac{1}{2} \sum_{o \in O} \sum_{d \in D} (s_{o,d}^1 - s_{o,d}^0) (\Delta v_{o,d} + \Delta b_{o,d} - c_{o,d}), \quad (12)$$

where the first term is the consumer surplus for the remaining drivers and the second term is the consumer surplus (which must be negative) for drivers priced off the road. The valuations are taken from the Swedish appraisal guidelines (Börjesson 2012; Börjesson and Eliasson 2014).

For private drivers using a company car, the congestion charge as an employee benefit is exempt from fringe-benefits tax. As explained in the introduction, most of the employers cover the congestion charge for employees with company cars, but even in cases where the employer does not pay, the employees pay from their gross income rather than their net income, which implies a substantial discount (approximately 70%, including payroll taxes, for employees in the high-income classes to which most who have access to a company car belong). The exemption (or discount) from the charge for company cars probably has a minor impact on the consumer surplus of the congestion charges: the (affluent) company car drivers would most likely not have been priced off the road even if they had paid the full charge. To simplify, we therefore assume that company car drivers pay the congestion charge in the CBA. However, for the distribution effects, the company car drivers’ possibility to avoid the charge will have a substantial effect on the distribution effect. We will return to it in “[Distribution of the gains and losses](#)” section, analysing the distribution of gains and losses.

Travel time variability

We measure travel time variability as the standard deviation of the travel time on the inner arterial links. Since travel time variability is not represented in the transport model we cannot calculate the benefit of reduced travel time variability at the OD-pair level. However, we can make a rough approximation of the magnitude of the effect of improved travel time variability relative to other effects using a simple link-based analysis. Now, the travel times on other links than the inner arterials in the direction toward the highway hub (depicted in Fig. 1) stay largely unaffected by the charges, and virtually all trips only use one of the inner arterials in the congested direction. Therefore, the standard deviation of the travel times on the arterial links corresponds well to the standard deviation of the travel times at the OD-pair level. Hence, we assume that the reduction in standard deviation of

the travel time on a given OD pair equals the reduction on the inner arterial belonging to this OD pair. There are four inner arterials, denoted l , and we have thus that $\sigma_{o,d} = \sigma_l$ if link l ($l = 1, 2, 3, 4$) belongs to OD pair o, d . None of the OD pairs includes more than one of the four links l .

Estimates of the ratio between the valuation of standard deviation and the valuation of mean travel time, usually denoted the reliability ratio, is close to unity for drivers in Sweden (Börjesson 2008, 2009). This corresponds well to what is found for other countries (Bates et al. 2001). We therefore apply the reliability ratio 1 in this paper.

The travel times by day and 10-min interval are available for 2012 and 2013 for the morning peak 7.00–9.00 (City of Gothenburg 2013a). Table 1 shows the standard deviation averaged over the twelve 10-min intervals in the peak, over 6 weeks in September and October for 2012 and 2013.

The total yearly traffic volume in the morning peak 7.00–9.00 on the four inner arterial links is 22,600,000 vehicles. The total daily traffic volume on these links is roughly five times the volume in the morning peak: 100 million. We assume that standard deviation in the travel times for all traffic outside the morning peak 7.00–9.00, is on average 25% of the reduction in the morning peak. This means that the benefit from the improved travel time variability is approximately twice that of the morning peak or €1,500,000 per year. The results show (“Result: CBA” section) that this benefit is small in relation to the benefit of shorter travel time. Hence, the approximation error we make from assessing the reduced travel time variability on a link basis is small.

Public transport

The producer surplus for the transit operator is obtained by subtracting the costs for providing additional capacity to the drivers diverting to public transport from the additional fare revenues. From 2012 to 2013 the transit ridership and sales of monthly and yearly tickets increased by seven per cent, but approximately two per cent is due to factors other than the congestion charges (Börjesson and Kristoffersson 2015). The sales of monthly and annual travel cards had increased on average by two per cent yearly over several years prior to 2012, due to population growth and various marketing campaigns continuing during 2013. Hence, the increase due to the congestion charges is probably around five per cent. The number of public transport trips also increased by five per cent in the charged OD pairs according to the travel survey conducted before and after the introduction of the charges (City of Gothenburg 2013b). The five per cent increase in sales of monthly and

Table 1 The standard deviation of the travel time on the four inner arterial links, and the calculated benefit from the reduction

	Number trips 7–9 am 2013	SD (min)			VTT (€/h)	Benefit (€)
		2012	2013	Reduction		
Bäckebo—Tingstad	11,100,000	2.3	2.2	0.1	8.7	170,000
Ullevi—Tingstad	5,600,000	1.2	1.0	0.1	8.7	90,000
Munkeböck—Tingstad	3,700,000	1.3	1.0	0.3	8.7	180,000
Kalleböck—Tingstad	2,200,000	2.6	1.6	1.0	8.7	310,000
Sum	22,600,000					750,000

annual travel cards corresponds to a €8 million increase in yearly revenue for the public transport operator.

The operating cost for public transport in the entire county (larger than the metropolitan area) increased by five per cent corresponding to €32 million/year. However, the operating costs increased even more in the previous years (yearly increases of 5–11%), suggesting that it was not directly the increased public transport demand due to congestion charges that increased the operating costs (Västra trafik 2013). Moreover, in Gothenburg crowding in the public transport system is a minor problem, so one could also argue that additional public transport supply to reduce crowding was not required (the share of buses and commuting trains where anyone had to stand up was less than three per cent in 2013 (Björklind et al. 2014)). For this reason, we assume that the increase in operating costs for the public transport producer is entirely covered by the additional fare revenues from new travellers (on average fare revenues cover approximately 50% of the operating costs). We also assume that the value of time for public transport users does not increase due to increased crowding.

External costs

The external costs of car use are taken from the Swedish CBA guidelines (ASEK 2014). It is in total €0.073 per vehicle kilometre, the components being traffic safety (€0.022 per vehicle kilometre), noise (€0.019 per vehicle kilometre), emissions other than CO₂ (€0.009 per vehicle kilometre) and CO₂ emissions (€0.023 per vehicle kilometre). All these components depend on the local environment, and we use the costs for city environments, where the external cost per vehicle kilometre is assumed to be higher than the national averages.

Government cost and revenue

The government's costs and revenues come from the paid charges, changes in fuel tax, and operating and maintenance costs of the charging system. The revenue from the paid charge is only a transfer from the drivers. The fuel tax corresponds to approximately €0.059 per vehicle kilometre, which is slightly less than the external cost.

According to the Swedish Transport Agency, the budget for the Gothenburg extension was €76 million, but only approximately half of that was a direct cost for the Gothenburg system (infrastructure, roadside, project management, testing of the system, information and education). The other half (€35 million) of the total budget was a cost for developing a new national central system for Swedish congestion charges. The central system of the original Stockholm system was developed and managed by IBM up until 2012. When congestion charging was introduced in Gothenburg, this had to be replaced by a national central system. A new central system was also necessary to impose taxes on new bridges in some smaller cities. In 2013, the operation cost of the Stockholm and the Gothenburg system was €24 million in total.⁶ Since the revenue is similar in the two systems, we assume that the operating and maintenance cost of the charging system was €12 million in

⁶ <https://www.transportstyrelsen.se/sv/Press/Kommentarer-och-fortydliganden/Vad-kostar-det-att-ta-ut-trangskattinfrastrukturavgift->.

2013. This is substantially lower than the operating cost of the Stockholm system for the first year and substantially lower than the operating cost of the London system.⁷

Marginal cost of public funds

According to the Swedish CBA guidelines, net public expenditure should be multiplied by the marginal cost of public funds (MCPF). The underlying assumption is that an infrastructure investment requires a marginal increase in the tax revenue (assuming that total public expenditure on other measures remains constant). Sørensen (2010) estimates MCPF to 1.3 in Sweden.

In the case of revenue generated from congestion charges, the analogous argument can be made; if the revenue from congestion charges allows a marginal reduction in tax revenue (assuming that total public expenditure on other measures remains constant) the revenue should be multiplied by the MCPF, or accounted for in the welfare measure in some other way as in Mayeres and Proost (2001). However, since the Gothenburg congestion charges were introduced to finance an infrastructure investment package that would not have been realized had the congestion charges not been implemented, this assumption may be contested. The political agreement (West Swedish Agreement, October 28, 2009) explicitly required partial funding from congestion charges of an investment package. For this reason, we do not include MCPF in the net social benefit of the congestion charges. On the other hand, the share of the investment cost of the package that is covered by the revenue from the congestion charges should not be multiplied by the MCPF in the CBA of the investment package.

Result: CBA

Table 2 summarizes the result of the cost–benefit analysis. The figures in the left column are computed under the assumption that the value of time is constant in the population and hence that $\Delta v_{o,d} = \bar{\alpha} \left(T_{o,d}^0 - (1 - q_{o,d}) T_{o,d}^{1n} - q_{o,d} T_{o,d}^{1p} \right)$. The figures in the right column are based on (10), assuming that the value of time is distributed in the population, and that drivers in OD pairs where there is a choice between charged and uncharged routes are sorted between the routes with respect to their value of time.

Verhoef and Small (2004) and Börjesson and Kristoffersson (2014) show that ignoring heterogeneity in VTT in a system with uncharged routes leads to underestimation of social benefits, by disregarding the efficiency gains due to sorting of the drivers with respect to VTT. This sorting increases the value of the travel time savings by 43% (from €23 to €33 million). Taking sorting into account, the consumer surplus is €-46 million, corresponding to the average loss of €0.35 per vehicle crossing.

Table 2 shows that the Gothenburg congestion charging system generates a yearly net benefit, even if not accounting for the benefit of sorting drivers between routes with respect

⁷ The latest estimate for London is a yearly (April 2015 to March 2016) operation cost of £90.1 million (compared to the revenue of £258.4 million, 35%) (Transport for London 2016), which is still a large improvement compared to £141.4 million (compared to the revenue of 186.7 M£, 76%) for the first year after its introduction in London (Transport for London 2004). The investment cost for the Stockholm system, and the operation costs the first year was approximately €200 million (Eliasson 2009).

Table 2 Cost benefit analysis of the Gothenburg congestion charges

	Loss/gain M€/year	
	Constant VTT	VTT distribution
Paid charge	– 77	– 77
Travel time saving	23	33
Travel time variability saving	2	2
Driving cost increase	– 1	– 1
Loss for evicted drivers	– 3	– 3
Consumer surplus	– 56	– 46
Traffic safety effects	2	2
Noise reduction	2	2
Pollution reduction	1	1
Reduction of CO2 emissions	2	2
External effects	7	7
Paid charge	77	77
Fuel tax decrease	– 6	– 6
Operating cost	– 12	– 12
Government	59	59
Net social benefit, excl. investment cost	10	20

to their value of time. However, the table does not include the system investment cost. Assuming the investment cost of €76 million⁸, and the yearly social benefit from the right-hand column, €20 million, the system will have recovered the investment cost in terms of social benefits in a little < 4 years. In financial terms, investment cost is recovered after just over 1 year, the yearly revenue being €59 million.

The relative efficiency of the pricing scheme can be calculated as a ratio of the total net social benefits and the total revenue collected from the congestion charges. In this case, the relative efficiency is $20/77 = 0.26$ (the right column in Table 2). This can be compared to the Stockholm system, where the relative efficiency was $65/80 = 0.81$ (Eliasson 2009). Hence, the sum of money that is redistributed in the population compared to the social benefit is substantially larger in the Gothenburg case than in the Stockholm case.

The consumer surplus can be split up by trip purpose according to Fig. 2. As expected, a majority of the travel time savings accrue to business and freight trips due to their high value of time, even though private car drivers (work trips and other) pay a large part of the revenue.

The large redistributions of money compared to the social surplus is one argument for carefully considering the redistribution effects, which is the topic of the next section.

⁸ As noted in “Government cost and revenue” section, half of this cost could be attributed to the update of national central system for congestion charges (that had to be done when extending the system from Stockholm only). Taking this into account would increase the relative efficiency.

Fig. 2 Consumer surplus by trip purposes

Distribution of the gains and losses

In this section we explore how the gains and losses are distributed across segments of the population. In “[Method](#)” section we describe the method of computing between different income groups. In “[Data](#)” section we describe the data that is input to this income distribution analysis and in “[Result: Income](#)” section we describe its result. In “[Result: Gender and age](#)” section we summarize the distribution effect with respect to age, and gender. In “[Geographical distribution effects](#)” section we compare how the gains and losses differ across residential locations with different voting outcome in the referendum.

Method

We assume that the gains and losses of the reform for a given individual depend on (i) the travel time reduction per trip and the value of time, (ii) the frequency of charged trips, (iii) access to company car for private trips (and we assume that company car drivers do not pay the charge). These factors are all functions of income (but depend on other factors too), and gains and losses depend therefore on the income level. The frequency of charged trips varies across income classes, not only because high-income commuters in general have higher car use, but also because individuals in different income classes are unevenly distributed across residential areas (and the driving patterns depend on residential location).

The transport model operates at a zonal level. The zones are 0.1–1 km² in built-up areas. The population of residents in each zone o is divided into 12 different income classes i . The number of individuals in each income class i in zone o is n_o^i . To compute the gains and losses for drivers by residential zone and income class, we need (i)–(iii) by residential zone and income class. Since only trips originating from the resident zone can be linked to the residents of each zone, we restrict the distribution analysis to commuting trips. Other trips do not always start in the zone where the driver resides.

Distribution analyses of the gains and losses normally focus on how the gains and losses, converted to money units, are distributed in the population. However, one could

argue that it is more relevant to study how the distribution of the effect on welfare (utility) varies across the population, to avoid placing a higher weight on travel time gains made by groups with lower marginal utility of money. We will describe the differences here. Assume (I) that the marginal utility of time varies in the population, but is independent of income, and (II) that the marginal utility of money depends on income but not on any other variable. Admittedly these assumptions are strong, but are at least consistent with the marginal utility for money being the Lagrange multiplier relating to the income constraint and marginal utility for time being the Lagrange multiplier relating to the time constraint (DeSerpa 1971; Jara-Díaz and Guevara 2003).

Assume that the average value of time for travellers in income class i is $\bar{\alpha}_i$ and let Ω_i be the social weight of individuals in income class i . For simplicity we leave out drivers priced off the road and the drivers choosing to take a detour to avoid paying the congestion charge. The welfare change for a representative traveller j in income class i and OD pair (o, d) , is then

$$\Delta V_{ij} = \Omega_i \left(v_j \left(T_{o,d}^0 - T_{o,d}^1 \right) + \tau_i \Delta b_{o,d} - \tau_i c_{o,d} \right) \quad (13)$$

where v_j is the marginal utility of time for individual j , τ_i is the marginal utility of money for income class i and Ω_i is the social weight of individuals in income class i . This can be compared to the change in consumer surplus W_{ij} for a representative traveller j in income class i and OD pair (o, d) ,

$$\Delta W_{ij} = \left(v_j / \tau_i \left(T_{o,d}^0 - T_{o,d}^1 \right) + \Delta b_{o,d} - c_{o,d} \right). \quad (14)$$

Comparison of (13) and (14) shows that using (14) as a welfare measure implies that the social weights are inversely proportional to marginal utilities of money, i.e., $\Omega_i = \frac{1}{\tau_i}$. This is one of the main points in Galvez and Jara-Díaz (1998).

To avoid putting higher weights on high-income travellers, an often used solution is to apply the same value of time for travellers (Mackie et al. 2001). However, many studies show that income differences explain a limited part of the variation in the values of time in the population (Börjesson and Eliasson 2012; Fosgerau 2007; Ramjerdi et al. 2010), presumably because the variation in marginal utility of time is large. In our distribution analysis we therefore convert the welfare change (13) to monetary units by dividing it with the average marginal utility of money $\bar{\tau}$ across all income classes and setting the social weight $\Omega_i = 1$ for all income classes

$$\Delta W_{ij} = \left(v_j / \bar{\tau} \left(T_{o,d}^0 - T_{o,d}^1 \right) + \tau_i / \bar{\tau} \Delta b_{o,d} - \tau_i / \bar{\tau} c_{o,d} \right).$$

The aggregate welfare change for all the remaining drivers in income class i travelling in OD pair (o, d) is then

$$\begin{aligned} \Delta W_i &= \sum_{j \in i} \left(\frac{v_j}{\bar{\tau}} \left(T_{o,d}^0 - T_{o,d}^1 \right) + \frac{\tau_i}{\bar{\tau}} \Delta b_{o,d} - \frac{\tau_i}{\bar{\tau}} c_{o,d} \right) \\ &= n_o^i \delta_{o,d}^i \left(\bar{v} / \bar{\tau} \left(T_{o,d}^0 - T_{o,d}^1 \right) + \tau_i / \bar{\tau} \Delta b_{o,d} - \tau_i / \bar{\tau} c_{o,d} \right), \end{aligned} \quad (15)$$

where n_o^i is the total number of individuals in income class i residing in zone o and $\delta_{o,d}^i$ is the average number of trips per day in charged OD pairs.

If our assumptions (I) and (II) do not hold, (15) might over- or underestimate the redistribution effect. For instance, if the average marginal utility of time increases with income, we will underestimate the gains of the charges for high-income travellers and vice versa.

The variables (i)–(iii) by income class and zone are derived as follows:

(i) Travel time gains

The value of time for income class i is assumed to be lognormally distributed $\ln \mathcal{N}(\ln \tilde{\alpha}_i, \sigma^2)$, where $\tilde{\alpha}_i$ is the median VTT for income group i . This VTT distribution is consistent with our assumptions (I) and (II) if the marginal utility of time, v , is distributed as $\ln \mathcal{N}(\ln(\tilde{\alpha}\bar{\tau}), \sigma^2)$, where $\tilde{\alpha}\bar{\tau}$ is the median marginal utility of time, independent from income. The VTT for income class i is then distributed as $\ln \mathcal{N}(\ln(\tilde{\alpha}\bar{\tau}), \sigma^2)/\tau_i = \ln \mathcal{N}(\ln(\tilde{\alpha}\bar{\tau}/\tau_i), \sigma^2)$. Hence, the median value of time for income class i , $\tilde{\alpha}_i$, is $\tilde{\alpha}\bar{\tau}/\tau_i$. Now the mean value of time $\bar{v}/\bar{\tau}$ equals $\bar{\alpha} = e^{\tilde{\alpha} + \sigma^2/2}$ and this is consistent with “Consumer surplus” section.

The ratio $\tau_i/\bar{\tau}$ is also needed to evaluate the welfare measure (14). We assume that $\tau_i/\bar{\tau}$ equals 1 for the middle-income class 5. To compute $\tau_i/\bar{\tau}$ for other income classes, we assume the income elasticity on τ_i to be $-e$. Under assumptions (I) and (II), e is the income elasticity of the value of time. We apply the elasticity $e = 0.5$, estimated in the Swedish 2008 value of time study (Börjesson and Eliasson 2014).

(ii) Frequency of charged trips

For each zone o that the transport model generates, the total number of trips in charged OD pairs is s_o^1 . The model does not generate s_o^1 by income class. However, the number of trips per individual in charged OD pairs by income class i , δ_i , can be approximated from the distribution of charged trips by income class derived from the two-wave survey described in “Data” section. Assume $\delta_i = \sum_{o,d} n_o^i \delta_{o,d}^i / \sum_o n_o^i$ and that the share of all trips in charged OD pairs in zone o , s_o^1 , that are made by the individuals in income class i is

$$r_o^i = \frac{\delta_i n_o^i}{\sum_{i \in I} \delta_i n_o^i}. \quad (16)$$

The average number of trips per individual in charged OD pairs in income class i residing in zone o , $\delta_{o,d}^i$, is approximated as $r_o^i \sum_{d \in D} s_{o,d}^1 / n_o^i$.

(iii) Access to company car

We know the average number of company cars accessible for private trips per individual by income class (see “Data” section). We assume that this distribution is constant across all zones (however, the distribution of the income classes varies across zones). From this we calculate the share of the drivers with access to a company car in each income class, γ_i , not paying the congestion charge.

Welfare effect

The travel time savings for remaining drivers in (15), $\bar{v}/\bar{\tau}(T_{o,d}^0 - T_{o,d}^1)$, equals $\Delta v_{o,d} = \bar{\alpha}(T_{o,d}^0 - T_{o,d}^1)$ in (5). However, if we also include the drivers that can choose to take a detour to avoid paying the congestion charge (disregarded in (15)) the value of the travel

time savings, $\Delta v_{o,d}^i$, will depend on income class due to sorting between the routes depending on the value of time.

To compute $\Delta v_{o,d}^i$, we compute the share of paying and non-paying drivers by zone and income class, $q_{o,d}^i$. As in “Consumer surplus” section, $k_{o,d}$ is the threshold VTT between paying and non-paying drivers in each OD pair. Based on the value of time distribution for income class i and $k_{o,d}$, we compute the share of paying drivers by income class and OD pair

$$\begin{aligned} q_{o,d}^i &= \int_{k_{o,d}}^{\infty} \ln \mathcal{N}(\xi; \ln(\tilde{\alpha}_i), \sigma^2) d\xi = \int_{k_{o,d}}^{\infty} \ln \mathcal{N}\left(\xi; \ln\left(\tilde{\alpha} \frac{\bar{\tau}}{\tau_i}\right), \sigma^2\right) d\xi \\ &= \Phi\left(\frac{\ln k_{o,d} - \ln\left(\tilde{\alpha} \frac{\bar{\tau}}{\tau_i}\right)}{\sigma}\right) = \Phi\left(\frac{\ln(k_{o,d} \frac{\tau_i}{\bar{\tau}}) - \ln \tilde{\alpha}}{\sigma}\right) \\ &= \int_{k_{o,d} \frac{\tau_i}{\bar{\tau}}}^{\infty} \ln \mathcal{N}(\xi; \ln \tilde{\alpha}, \sigma^2) d\xi \end{aligned} \quad (17)$$

To compute $\Delta v_{o,d}^i$, we also need the partial expectation of the welfare change for income class i , $g_{o,d}^i = \int_{k_{o,d} \frac{\tau_i}{\bar{\tau}}}^{\infty} \xi \ln \mathcal{N}(\xi; \ln \tilde{\alpha}, \sigma^2) d\xi$. Applying an equivalent derivation to that for (10), we have

$$\Delta v_{o,d}^i = \bar{\alpha} T_{o,d}^0 - \left((\bar{\alpha} - g_{o,d}^i) T_{o,d}^{1n} + g_{o,d}^i T_{o,d}^{1p} \right). \quad (18)$$

Replacing $\bar{v}/\bar{\tau}(T_{o,d}^0 - T_{o,d}^1)$ with $\Delta v_{o,d}^i$ in (15) to include drivers in OD pairs with the possibility of avoiding the charges by a free route, the aggregate welfare effect for the remaining drivers in income class i is

$$\Delta W_i = \sum_{o \in O} \sum_{d \in D} r_o^i s_{o,d}^1 \left(\Delta v_{o,d}^i + \tau_i / \bar{\tau} \Delta b_{o,d}^i - \tau_i / \bar{\tau} c_{o,d}^i \right), \quad (19)$$

where $\Delta b_{o,d}^i = \beta \left(D_{o,d}^0 - \left((1 - q_{o,d}^i) D_{o,d}^{1n} + q_{o,d}^i D_{o,d}^{1p} \right) \right)$, $c_{o,d}^i = q_{o,d}^i C$ and $n_o^i \delta_{o,d}^i$ is approximated with $r_o^i s_{o,d}^1$. In the distribution analysis applying (19), we do not calculate the number of drivers priced off the road by income class. As shown in Table 2, their loss is relatively small compared to the loss for the remaining drivers.

The welfare measure (19) does not assign the travel time saving of high-income individuals a higher weight than the travel time savings of low-income individuals. Note that we still consider that the marginal utility of time is distributed, and thereby keep the benefit of sorting between routes in the analysis.

Data

The frequency of charged trips in different segments of the population is derived from a two-wave travel survey conducted in Gothenburg in November 2012 and November 2013 (Börjesson et al. 2016). The surveys were sent to random samples of adult residents in central parts of the Gothenburg region (the municipalities of Göteborg, Mölndal, Partille and Öckerö, and the postal areas Mölnlycke and Landvetter in Härryda municipality),

Table 3 Number of charged trips per day (δ) for each income class

Income €/month	δ_i
–1500	0.16
1501–2500	0.29
2501–3500	0.40
3501–4500	0.49
4501–	0.56
Average all individuals in the survey	0.35

resulting in 1582 (2012) and 1426 (2013) useable responses, with response rates of 40% and 38%, respectively.

The survey included questions on travel behaviour, access to cars and company cars in the household, socio-economics and opinion of congestion charging and parking fees. It included a broad set of questions on various topics to avoid policy bias. The respondents were reminded of the design of the charging system by showing a map and times when the charge applies. The respondents were asked how often they paid the congestion charge (or would pay it in the 2012 wave).

Table 3 reports the frequency of charged trips by income class according to the survey. The six income classes in the survey do not match the twelve income classes in the transport model. The trip frequencies in Table 3 were therefore interpolated to the income classes in the model, as shown in Table 4.

Table 4 also shows the median and mean value of time by income class. It is computed under the assumption that the value of time distribution for income class five equals the distribution estimated for the Swedish population, and the income elasticity $e = 0.5$.

The last column of Table 4 shows the share of the drivers with access to a company car for private trips, γ_i . This is taken from national statistics (Ynnor 2014) and it corresponds well to the distribution in the two-wave Gothenburg survey. Surprisingly many of the drivers with very low income (less than €8000 per year) have access to a company car, which makes the distribution of this variable U-shaped. Presumably, these drivers are self-employed, and their firms generate profit that does not count as income in the registers.

Table 4 Median VTT ($\tilde{z}_i$), mean VTT ($\bar{z}_i$), paying trips per day (δ_i) and share of the drivers with access to company car (γ_i) by income class

i	income (k€/year) ^a	$\tilde{z}_i$ (€/h)	$\bar{z}_i$ (€/h)	δ_i	γ_i (%)
0	0	0.0	0.0	0.00	0.0
1	0.1–3.9	1.7	3.6	0.04	55.1
2	4–7.9	3.0	6.2	0.11	26.0
3	8–11.9	3.8	8.0	0.17	10.3
4	12–15.9	4.5	9.5	0.23	7.1
5	16–19.9	5.1	10.8	0.28	6.1
6	20–23.9	5.7	11.9	0.33	5.9
7	24–27.9	6.2	13.0	0.38	8.4
8	28–31.9	6.6	13.9	0.42	15.1
9	32–35.9	7.1	14.8	0.46	22.9
10	36–39.9	7.5	15.7	0.49	33.1
11	40.0–	7.8	16.5	0.53	64.9

^aWhen computing the value of time for income class i applying the elasticity 0.5, we assume the income in each class is the mid-point in the interval

Fig. 3 Gains and losses per trip by income class for car commuters in Gothenburg

Still, drivers in income classes 0–6 have a total company car share of 10%, while drivers in income classes 7–11 have a share of 28%.

Table 4 includes all data needed to compute (i)–(iii) by income class and residential zone.

Result: income

Figure 3 shows the net gain per car trip by income class according to the welfare measure (19),

$$\frac{\sum_{o \in O} \sum_{d \in D} r_o^i s_{o,d}^1 \left(\Delta v_{o,d}^i + \tau_i / \bar{\tau} \Delta b_{o,d}^i - \tau_i / \bar{\tau} c_{o,d}^i \right)}{\sum_{o \in O} r_o^i \sum_{d \in D} s_{o,d}^1}. \quad (20)$$

The gains are computed as

$$B_i = \frac{\sum_{o \in O} \sum_{d \in D} r_o^i s_{o,d}^1 \left(\Delta v_{o,d}^i \right)}{\sum_{o \in O} r_o^i \sum_{d \in D} s_{o,d}^1},$$

and the losses are computed as

$$L_i = \frac{\sum_{o \in O} \sum_{d \in D} r_o^i s_{o,d}^1 \left(\tau_i / \bar{\tau} \Delta b_{o,d}^i - \tau_i / \bar{\tau} c_{o,d}^i \right)}{\sum_{o \in O} r_o^i \sum_{d \in D} s_{o,d}^1}.$$

Figure 3 shows that all drivers but those in the highest income segment are worse off with the charges. In general, the income has a larger impact on the losses than on the gains. The income effect on the losses is driven by the income effect on the marginal utility of money. The income effect on the gains is small because all drivers experience similar travel time reductions and all income classes are assumed to have the same marginal utility of time. There is still some income dependence, partly because drivers in the higher income segments make fewer detours to avoid the congestion charge.

Figure 4 is equivalent to Fig. 3 but derived based on the standard welfare rule (14) instead of (19). We see that the standard welfare measure places a higher weight on the

Fig. 4 Gains and losses per trip by income class for car commuters in Gothenburg, calculated based on welfare measure (14)

Fig. 5 Total gains and losses for commuting per individual by income class

gains of high-income drivers due to their lower marginal utility of money. On the other hand, high-income classes also lose more according to welfare measure (19). In total, the welfare measure (19) shows larger re-distribution effects, because paying charges are more painful for low-income classes due to the higher marginal utility of money.

To analyse the distribution effects of the congestion charge, it is, however, more relevant to consider the full population and not only the drivers. Such an analysis takes into account that high-income individuals undertake charged trips more frequently than low-income individuals. Figure 5 shows the welfare effect per individual by income class

$$\frac{W_i}{n^i} = \frac{\sum_{o \in O} r_o^i \sum_{d \in D} s_{o,d}^1 \left(\Delta v_{o,d}^i + \tau_i / \bar{\tau} \Delta b_{o,d}^i - \tau_i / \bar{\tau} c_{o,d}^i \right)}{\sum_{o \in O} n_o^i}. \quad (21)$$

Again, the gains are computed based on the first term in (21) and the losses are computed based on the second and the third term. Now the net gain first decreases and then increases with income, such that the mid-income classes are worse off. The re-distribution

Fig. 6 Total gains and losses per individual by income class, calculated based on welfare measure (14)

effects are smaller than in Fig. 3, because individuals with higher incomes undertake charged trips more frequently. In fact, the richest third pays three times more than the poorest third. This is similar to what Eliasson and Mattsson (2006) found for Stockholm.⁹ For the top income class, the losses are still offset by the gains due to the considerably higher access to company cars and their low marginal utility of money.

Figure 6 shows that gains and losses based on welfare measure (14). It shows again that individuals in all income classes, but the top income class are on average worse off with the charges. The loss increases faster with income than in Fig. 5, because their losses are not reweighted to take into account that the marginal utility of money reduces with income. However, the gains are also larger for high-income groups due to their higher value of time, and the distribution effects are similar to Fig. 5. However, if the gains and losses computed by welfare measure (14) are divided by income, as in Fig. 7, we find, again, that the net loss in relative terms decreases with income.

Figure 5 and Fig. 7 give slightly different pictures of the distribution effects—the key difference being that in Fig. 7 we assign a higher weight to the travel time savings accruing to the higher income groups; on the other hand we measure the net gain in relative terms. Hence, the welfare measure and whether we focus on absolute or relative gains and losses matter.

As noted, in Gothenburg the revenues are not spent to improve the local public transport system to benefit local low-income classes. Rather, it is spent on a rail tunnel that will mainly benefit commuters further out in the region many years ahead (see “[The Gothenburg congestion charges](#)” section). As long as a congestion charge is justified from the perspective of economic efficiency and to price externalities, negative distribution effects may be less controversial. But since the congestion charge in Gothenburg is mainly implemented for fiscal reasons, to finance the rail tunnel and other infrastructure projects, one might be more concerned with the distribution effects.

⁹ They found that the richest third pays four times more than the poorest third, but at that time company car drivers had to pay the charge from their net income.

Fig. 7 Total gains and losses divided by the income per individual by income class, calculated based on welfare measure (14)

Result: gender and age

We continue by analysing the gains and losses by gender and age group. According to the survey, men and women undertake on average the same number of charged trips per day. According to the value of time study, the average value of time is equal for men and women. However, twenty-eight per cent of the men, but only six per cent of the women, have access to a company car (Ynnor 2014). This means that men and women benefit from the charges to the same extent, but women on average suffer larger losses than men.

According to the survey, the average frequency of charged trips differs by age group. Also, access to a company car differs by age group; see Table 5. The value of time study, however, does not reveal any age differences. Taking account of the age effect on the frequency of charged trips and the access to company cars, the distribution of gains and losses is distributed between age groups according to Fig. 8 (here we have used welfare measure 14 since the value of time does not differ between groups). The age group 56–65 years suffers the largest losses, and the group 36–55 benefits the most. The net loss is fairly constant across all groups except for the oldest.

Geographical distribution effects

Finally, we analyse the geographic distribution of gains and losses. We also compare them to the outcome of the referendum held in September 2014, to explore the extent to which the outcome of the referendum is driven by self-interest. We assume that the charges have

Table 5 Paying trips per day and share of drivers with access to company car for each age group

Age group	δ_i	γ_i
18–25	0.26	0.05
26–35	0.32	0.03
36–55	0.45	0.14
56–65	0.41	0.10
66–75	0.26	0.04
over 75	0.12	0.01

Fig. 8 Gains and losses of the charge by age group for all individuals in Gothenburg

Fig. 9 Geographical distribution of loss

Fig. 10 Geographical distribution of time gain

no impact on the geographical location of the individuals (i.e., that they do not induce spatial sorting).

Figure 9 shows the loss per individual by zone of residence. Residents of the neighbourhood just outside the toll cordon pay the most, because of their high frequency of charged trips. Figure 10 shows that the largest travel time gains are concentrated along the highways, especially along the north–south link, E6, where the travel times reduced the most. Figures 9 and 10 combined show that residents of neighbourhoods north and west of the toll cordon, where the average income is low, suffer the largest net losses. They have high marginal utility of money and low access to company cars. The residents of the inner city both gain and lose less than the residents just outside the cordon, because they undertake fewer charged trips.

Figure 11 shows the referendum results. The referendum was only held in the municipality of Gothenburg. It demonstrates that residents of central Gothenburg are more positive to the charges, whereas residents further out in the region are more negative. This pattern is consistent with the pattern of losers of the charges in Fig. 10; residents further out in the municipality lose more. However, the darkest areas in Fig. 11, east and south-west of the charging zone, where the residents are most positive, also lose a lot from the charges. Therefore, no correlation was found between voting pattern and gains, losses or

Fig. 11 Geographical distribution of referendum results

net gain. This is consistent with Börjesson et al. (2016), showing that the attitudes to congestion charges are not only formed by self-interest, but also by more stable political attitudes such as environmental concern and general opinions regarding taxation. However, Hårsman and Quigley (2010) find that voting districts in Stockholm, with larger net benefits from the congestion charges, show stronger support for the charges.

Conclusions

Although Gothenburg is a small city with congestion limited to the highway junctions, the congestion charge scheme is socially beneficial, generating a net surplus of €20 million per year. From a financial perspective, the investment cost was repaid in slightly more than a year and, from a social surplus perspective, is repaid in < 4 years. The social benefit of €20 million per year is similar to that of Milan, but much lower than the social benefit of the Stockholm and London systems. The operation cost of the Gothenburg system is also lower than it was in Stockholm, because it could be set up as extensions of the Stockholm system. Still, the sums that are redistributed in Gothenburg are substantially larger than the net benefit. The low relative efficiency of the policy stems from the lower congestion levels,

implying smaller travel time benefits. Since many small cities have low congestion levels, low relative efficiency is likely to be a general problem for small cities.

Due to the large sums that are redistributed compared to the welfare gain, the distribution analysis is central. The standard welfare measure shows that the congestion charge is regressive. This is partly because even low-income individuals are highly car-dependent in the charged OD pairs in Gothenburg (much more than in the charged OD pairs in Stockholm), due to the relatively low population density and public transport share (26% in the charged OD pairs). Another reason is that workers in the highest income class have considerably higher access to company cars for private trips, and thereby the employer pays the congestion charge on behalf of the employee as a tax-free benefit. For this reason, new legislation will come into force in January 2018 stating that company car users are taxed when the employers pay the congestion charge for private trips (including commuting) (Ministry of Finance 2017). The negative distribution effects due to the company car legislation might not be transferable to small cities in other countries. However, the high car dependence for commuting even for low-income groups is probably also a general problem for many small cities. As a comparison, Eliasson et al. (2016) show the fuel taxes and purchase tax on new cars are progressive over most of the income distribution.

Men and women benefit from the charges to the same extent because they make the same number of charged trips. However, fewer women on average have access to a company car for commuting trips and suffer larger losses than men. The net loss is fairly constant across age groups, except for the oldest (over 75), who drive less.

The average change in consumer surplus is negative for all income classes but the highest. Since most residents of Gothenburg suffer a net loss from the charges, and because the distribution of the direct effects of the charges is regressive, how the revenue is spent is decisive for the total effect on equity. However, the revenue is spent mainly on a rail tunnel which primarily benefits commuters from surrounding municipalities in the region. This could be one important reason behind the low public support for the charges.

Acknowledgements This project was funded by the Swedish Transport Administration and Vinnova (2013-03091). This paper was presented at the 2017 Annual Conference and School of the International Transportation Economics Association, ITEA, Barcelona, Spain, June 19–23.

Authors' contributions J West: Data Analysis, Modelling, and Manuscript Writing. M Börjesson: Literature Review, Data Analysis, Manuscript Writing, and Editing.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

References

- Arnott, R., De Palma, A., Lindsey, R.: The welfare effects of congestion tolls with heterogeneous commuters. *J. Transp. Econ. Policy* **28**, 139–161 (1994)
- ASEK: Beräkningsmetodik och gemensamma förutsättningar för transportsektorns samhällsekonomiska analyser. Guidelines for Welfare Analysis Methodology in the Transport Sector. The Working Group for Appraisal Analysis, Transport Administration (2014)

- Bates, J., Polak, J., Jones, P., Cook, A.: The valuation of reliability for personal travel. *Transp. Res. Part E Logist. Transp. Rev.* **37**, 191–229 (2001). [https://doi.org/10.1016/S1366-5545\(00\)00011-9](https://doi.org/10.1016/S1366-5545(00)00011-9)
- Björklind, K., Danielsson, J., Lindholm, P., Björk, H., Coulianos, M., Tjernkvist, M.: Första året med Västsvenska paketet (The First Year with the West-Swedish package) (No. 2014:3) (2014)
- Börjesson, M.: Joint RP-SP data in a mixed logit analysis of trip timing decisions. *Transp. Res. Part E* **44**, 1025–1038 (2008)
- Börjesson, M.: Modelling the preference for scheduled and unexpected delays. *J. Choice Model.* **2**, 29–50 (2009)
- Börjesson, M.: Valuing perceived insecurity associated with use of and access to public transport. *Transp. Policy* **22**, 1–10 (2012). <https://doi.org/10.1016/j.tranpol.2012.04.004>
- Börjesson, M., Eliasson, J.: Experiences from the Swedish Value of Time study (CTS Working Paper No. 2012:8). CTS Working Paper. Centre for Transport Studies, KTH Royal Institute of Technology (2012)
- Börjesson, M., Eliasson, J.: Experiences from the Swedish Value of Time study. *Transp. Res. A* **59**, 144–158 (2014)
- Börjesson, M., Kristoffersson, I.: Assessing the welfare effects of congestion charges in a real world setting. *Transp. Res. Part E Logist. Transp. Rev.* **70**, 339–355 (2014). <https://doi.org/10.1016/j.tre.2014.07.006>
- Börjesson, M., Kristoffersson, I.: The Gothenburg congestion charge. Effects, design and politics. *Transp. Res. Part Policy Pract.* **75**, 134–146 (2015). <https://doi.org/10.1016/j.tra.2015.03.011>
- Börjesson, M., Kristoffersson, I.: The Swedish Congestion Charges: Ten Years On—And Effects of Increasing Charging Levels. CTS Work. Pap. 20172 (2017)
- Börjesson, M., Eliasson, J., Hugosson, M.B., Brundell-Freij, K.: The Stockholm congestion charges—5 years on. Effects, acceptability and lessons learnt. *Transp. Policy* **20**, 1–12 (2012). <https://doi.org/10.1016/j.tranpol.2011.11.001>
- Börjesson, M., Eliasson, J., Hamilton, C.: Why experience changes attitudes to congestion pricing: the case of Gothenburg. *Transp. Res. Part Policy Pract.* **85**, 1–16 (2016). <https://doi.org/10.1016/j.tra.2015.12.002>
- Carnovale, M., Gibson, M.: The Effects of Driving Restrictions on Air Quality and Driver Behavior. eScholarship (2013)
- City of Gothenburg: Restider i Göteborg—En jämförelse mellan 2012 och 2013 (Travel Times in Gothenburg—A Comparison Between 2012 and 2013) (2013a)
- City of Gothenburg: Förändrade resvanor: Trängselskattens effekter på resandet i Göteborg (Altered Travel Behaviour: The Congestion Charge and Its Effect on Travel in Gothenburg) (2013b)
- Danielis, R., Rotaris, L., Marcucci, E., Massiani, J.: A medium term evaluation of the Ecopass road pricing scheme in Milan: economic, environmental and transport impacts. *Econ. Policy Energy Environ.* **2012**, 49–83 (2012)
- de Palma, A., Lindsey, R.: Congestion pricing with heterogeneous travelers: a general-equilibrium welfare analysis. *Netw. Spat. Econ.* **4**, 135–160 (2004). <https://doi.org/10.1023/B:NETS.0000027770.27906.82>
- DeSerpa, A.C.: A theory of the economics of time. *Econ. J.* **81**, 828–846 (1971). <https://doi.org/10.2307/2230320>
- Eliasson, J.: A cost-benefit analysis of the Stockholm congestion charging system. *Transp. Res. Part Policy Pract.* **43**, 468–480 (2009). <https://doi.org/10.1016/j.tra.2008.11.014>
- Eliasson, J.: Is congestion pricing fair? Consumer and citizen perspectives on equity effects. *Transp. Policy* **52**, 1–15 (2016)
- Eliasson, J., Mattsson, L.-G.: Equity effects of congestion pricing: quantitative methodology and a case study for Stockholm. *Transp. Res. Part A* **40**, 602–620 (2006)
- Eliasson, J., Börjesson, M., van Amelsfort, D., Brundell-Freij, K., Engelson, L.: Accuracy of congestion pricing forecasts. *Transp. Res. Part Policy Pract.* **52**, 34–46 (2013). <https://doi.org/10.1016/j.tra.2013.04.004>
- Eliasson, J., Pyddoke, R., Swärdh, J.-E.: Distributional Effects of Taxes on Car Fuel, Use, Ownership and Purchases (No. 2016:X). CTS Working Paper. Centre for Transport Studies, KTH Royal Institute of Technology (2016)
- Evans, A.: Road congestion pricing: when is it a good policy? *J. Transp. Econ. Policy* **26**, 213–243 (1992)
- Fosgerau, M.: Using nonparametrics to specify a model to measure the value of travel time. *Transp. Res. A* **41**, 842–856 (2007). <https://doi.org/10.1016/j.tra.2006.10.004>
- Fridström, L., Minken, H., Moilanen, P., Shepherd, S., Vold, A.: Economic and Equity Effects of Marginal Cost Pricing in Transport (Research Reports No. 71). Government Institute for Economic Research Finland (VATT) (2000)
- Galvez, T.E., Jara-Díaz, S.R.: On the social valuation of travel time savings. *Int. J. Transp. Econ.* **25**, 205–219 (1998)

- Gibson, M., Carnovale, M.: The effects of road pricing on driver behavior and air pollution. *J. Urban Econ.* **89**, 62–73 (2015). <https://doi.org/10.1016/j.jue.2015.06.005>
- Glazer, A., Niskanen, E.: Which consumers benefit from congestion tolls? *J. Transp. Econ. Policy* **34**, 43–53 (2000)
- Härsman, B., Quigley, J.M.: Political and public acceptability of congestion pricing: ideology and self-interest. *J. Policy Anal. Manag.* **29**, 854–874 (2010). <https://doi.org/10.1002/pam.20529>
- Ison, S., Rye, T.: Implementing road user charging: the lessons learnt from Hong Kong, Cambridge and Central London. *Transp. Rev.* **25**, 451–465 (2005). <https://doi.org/10.1080/0144164042000335788>
- Jara-Díaz, S.R., Guevara, C.A.: Behind the subjective value of travel time savings. *J. Transp. Econ. Policy* **37**, 29–46 (2003)
- Levinson, D.: Equity effects of road pricing: a review. *Transp. Rev.* **30**, 33–57 (2010). <https://doi.org/10.1080/01441640903189304>
- Mackie, P.: The London congestion charge: a tentative economic appraisal. A comment on the paper by Prud'homme and Bocajero. *Transp. Policy* **12**, 288–290 (2005)
- Mackie, P., Jara-Díaz, S.R., Fowkes, A.S.: The value of travel time savings in evaluation. *Transp. Res. Part E* **37**, 91–106 (2001). [https://doi.org/10.1016/S1366-5545\(00\)00013-2](https://doi.org/10.1016/S1366-5545(00)00013-2)
- Mayeres, I., Proost, S.: Marginal tax reform, externalities and income distribution. *J. Public Econ.* **79**, 343–363 (2001). [https://doi.org/10.1016/S0047-2727\(99\)00100-0](https://doi.org/10.1016/S0047-2727(99)00100-0)
- Mellin, A., Nilsson, J.-E., Pyddoke, R.: Underlagsrapport till RiR 2011:28: Medfinansiering av statlig infrastruktur (2011)
- Ministry of Finance: Ändrad beräkning av bilförmån (Changed Calculation of Taxable Benefit Value) (No. Fi2017/01480/S1) (2017)
- Neuburger, H.: User benefit in the evaluation of transport and land use plans. *J. Transp. Econ. Policy* **5**, 52–75 (1971)
- Olszewski, P., Xie, L.: Modelling the effects of road pricing on traffic in Singapore. *Transp. Res. Part Policy Pract.* **39**, 755–772 (2005). <https://doi.org/10.1016/j.tra.2005.02.015>
- Phang, S.-Y., Toh, R.S.: From manual to electronic road congestion pricing: the Singapore experience and experiment. *Transp. Res. Part E Logist. Transp. Rev.* **33**, 97–106 (1997). [https://doi.org/10.1016/S1366-5545\(97\)00006-9](https://doi.org/10.1016/S1366-5545(97)00006-9)
- Prud'homme, R., Bocarejo, J.P.: The London congestion charge: a tentative economic appraisal. *Transp. Policy* **12**, 279–287 (2005)
- Ramjerdi, F., Flügel, S., Samstad, H., Killi, M.: Value of Time, Safety and Environment in Passenger Transport (No. Transportökonomisk institutt) (2010)
- Rye, T., Gaunt, M., Ison, S.: Edinburgh's congestion charging plans: an analysis of reasons for non-implementation. *Transp. Plan. Technol.* **31**, 641–661 (2008). <https://doi.org/10.1080/03081060802492686>
- Santos, G.: Double cordon tolls in urban areas to increase social welfare. *Transp. Res. Rec. J. Transp. Res. Board* **1812**, 53–59 (2002). <https://doi.org/10.3141/1812-07>
- Santos, G.: Urban road pricing in the UK. *Res. Transp. Econ.* **9**, 251–282 (2004). [https://doi.org/10.1016/S0739-8859\(04\)09011-0](https://doi.org/10.1016/S0739-8859(04)09011-0)
- Santos, G., Rojey, L.: Distributional impacts of road pricing: the truth behind the myth. *Transportation* **31**, 21–42 (2004)
- Santos, G., Shaffer, B.: Preliminary results of the London congestion charging scheme. *Public Works Manag. Policy* **9**, 164 (2004)
- Schiller, P.L.: High occupancy vehicle (HOV) lanes: highway expansions in search of meaning. *World Transp. Policy Pract.* **4**, 32–38 (1998)
- SL: Fakta om SL och länet 2012 (Facts About SL and the County 2012) (No. SL 2013-6099) (2013)
- Small, K.: The scheduling of consumer activities: work trips. *Am. Econ. Rev.* **72**, 467–479 (1982)
- Small, K.: The incidence of congestion tolls on urban highways. *J. Urban Econ.* **13**, 90–111 (1983)
- Sørensen, P.B.: Swedish Tax Policy: Recent Trends and Future Challenges. Finansdepartementet, Regeringskansliet (2010)
- Suits, D.B.: Measurement of tax progressivity. *Am. Econ. Rev.* **67**(4), 747–752 (1977)
- Transport for London: 03/04 Annual Report (2004)
- Transport for London: Annual Report and Statement of Accounts 2015/16 (2016)
- Västrafik: Årsredovisning 2013 (Public Transport Region West, Annual Report 2013) (2013)
- Verhoef, E., Small, K.: Product differentiation on roads. *J. Transp. Econ. Policy JTEP* **38**, 127–156 (2004)
- West, J., Börjesson, M., Engelson, L.: Accuracy of the Gothenburg congestion charges forecast. *Transp. Res. Part Policy Pract.* **94**, 266–277 (2016). <https://doi.org/10.1016/j.tra.2016.09.016>
- Xie, C.: Dynamic Decisions to Enter a Toll Lane on the Road (2013)
- Ynnor: Tjänstebilsmarknaden 2013/14 Statistik (2014)

Dr. Jens West works as an expert in the fields of transport modelling and transport economics in the Nordic countries, specialised in network assignment, cost-benefit analysis and the studies of congestion charges. Dr. West graduated from KTH Royal Institute of Technology in 2017. In his PhD thesis he studied the modelling of congested urban transport networks and appraisal methods in such conditions.

Dr. Maria Börjesson is Professor of Economics at VTI – Swedish Road and Transport Research Institute. She is also affiliated to the KTH Royal Institute of Technology in Stockholm, the Choice Modelling Centre at ITS Leeds and secretary of the board of International Transportation Economics Association (ITEA). She has been involved in the design process of the Gothenburg congestion charges and evaluated the charges in both Stockholm and Gothenburg. Her research interests include transport cost-benefit analysis, appraisal and sustainability, transport policy and pricing, public opinions, transport modelling, travel behaviour, gender differences, active mobility and cycling, the impact of the transport system on employment and GDP, survey design, choice experiments, and econometrics for valuation of non-market goods such as travel time, reliability and security.