Doctoral theses at NTNU, 2023:99

Doctoral thesis

Marie Aarestrup Aasness

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Norwegian University of Science and Technology
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ISBN 978-82-326-5512-0 (printed ver.)
ISBN 978-82-326-6618-8 (electronic ver.)
ISSN 1503-8181 (printed ver.)
ISSN 2703-8084 (online ver.)

Doctoral theses at NTNU, 2023:99

Printed by NTNU Grafisk senter

Contents

Abstract

Increasing road traffic volumes in urban areas worldwide pose challenges to the lives and livelihoods of humans living in urban areas from pollution that is detrimental to the health of urban populations, increases costs to industries due to time lost on congested road networks, and increases global warming due to emissions from internal combustion engine vehicles (ICEVs), e.g., CO2 emissions. Governments across the globe have taken these problems caused by road traffic seriously and have started to implement measures to circumvent them in recent decades. Measures taken by governments to reduce the abovementioned problems include but are not limited to (i) congestion charging to reduce traffic entering urban areas, (ii) increased parking charges to deter people from driving and parking in urban areas, (iii) creation of environmental zones that prohibit car use in certain areas within an urban area and (iv) encouraging the use of battery electric vehicles (BEVs), particularly through economic incentives such as exemptions from certain vehicle taxes and exemptions from paying road tolls. How these government measures work or have worked in practice has been addressed and is continuously being addressed in the literature on transportation economics and planning.

Although the literature has addressed how government efforts work in practice to reduce the problems caused by increasing traffic volumes, there are still several research-based questions that have not been addressed in the literature and that may enhance decision-making by governments. Among the gaps in the literature are questions such as

(i) How do road transport users experience congestion, not to be confused with how they experience "congestion charging"?

(ii) Given that there is an already existing flat rate toll in an urban area to collect funds for road building, what are the road user's attitudes towards a transformation to a

full-fledged congestion charging scheme to reduce the problems caused by congestion?

(iii) Given that governments implement financial incentives to motivate the purchase and use of BEVs, what are the adverse economic effects?

(iv) Given (iii) above, what are road users' attitudes toward such incentives several years after their implementation?

Answers to these questions will add to the knowledge available to decision-makers and to the transportation literature. For instance, decision-makers may want to know about the adverse effects of BEV incentives to help them better design or improve such incentives.

This thesis henceforth seeks to provide an understanding of road user attitudes and experiences towards congestion, congestion charging, and adverse effects of electric vehicle incentives not known to decision-makers at the time of their decision making. This understanding is important for decision-makers in devising effective management to ensure effective road transport systems that account for the urban environment in addition to global climate change. The thesis uses Oslo, Norway as a case study where toll charging, congestion charging, and BEV incentives have been in practice for years, and Norway is a front-runner worldwide in those respects. The approach used in the study is extensive questionnaire surveys in the larger Oslo area to measure the attitudes and experiences of road users. The methods used to assess the responses from the questionnaire surveys are well-known statistical logit models. To measure the adverse effects of BEV incentives, an ex post study in which real outturns after the implementation of the incentives were compared to ex ante estimates, i.e., estimates made before the implementation, formed the basis for decision making.

The main findings from the thesis are as follows.

1. Factors found to influence road users' experiences with congestion were as follows: whether they experienced congestion on their reference trip, how often road users undertake trips during congestion, the extent to which road users had potential alternative modes of transport other than car use, education, whether respondents had time commitments at their destinations, travel time used during their journey, how often they experience congestion as a problem during their journey, and when participants begin to experience discomfort with congestion and age.
2. The factors found to influence attitudes towards congestion charging were as follows: willingness to pay, whether the respondent is likely to drive a car, whether they have a positive view of train transport, age, educational level, whether they have had a negative experience with congestion, whether they agree that they experience less congestion with congestion charging in place, fuel type used and geographic location.
3. Among the adverse effects of BEV incentives, perhaps the most problematic is the sizeable loss of toll revenue.
4. People living in greater Oslo are starting to disapprove of beneficial BEV incentives such as toll exemptions, access to bus lanes without passengers and free public parking.

In addition to the main findings above, this thesis emphasizes factors that are important for decision makers to be aware of at the time of their decision-making. An example is road user attitudes toward unpopular policies such as congestion charging or changes in BEV economic incentives.

A potential area for further research on the topics covered in this thesis is a more in-depth study on the impact of psychological factors on attitudes and experiences with congestion. Our questionnaire surveys did not fully account for psychological factors, e.g., the extent to which frustration, annoyance or discomfort influence attitudes and experience. Another limitation of the study is that it does not account for the COVID-19 pandemic, although paper 4 used data for 2020 when the COVID-19 pandemic was at its peak. The questionnaire survey did not ask respondents specifically about COVID conditions and how it affected their travel patterns and/or their reasoning to purchase BEVs.

Acknowledgements

First, I would like to thank my main supervisor Professor James Odeck, who motivated me to start with a PhD in the first place, for his inspiring discussions and introducing me to his great network. Together with my co-supervisor Professor Svein Bråthen, I would also like to thank them for their invaluable feedback and support throughout the course of this PhD work. I highly appreciate your advice and suggestions.

I would also like to thank the Norwegian Public Roads Administration for financing my PhD studies, supplying data and giving me time to work on the thesis. Furthermore, I would like to thank the Oslo package 3 secretariat for supplying data.

Finally, but not least, I would extend my gratitude to my family, friends and colleagues for their understanding and support during this time.

1 Introduction

This section introduces the motivation behind the thesis, the research questions, and the structure of the thesis.

1.1 Context and motivation for the research

During my master's degree studies at the University of Oslo, I became interested in transport economics and wrote a master's thesis on converting the Oslo cordon toll system, which was a flat rate toll charging scheme meant to finance road building and other environmentally friendly means of transport such as public transport infrastructure and cycling facilities, to a congestion charging scheme (Aasness 2008). That master's thesis was instrumental for my employment at the Norwegian Public Roads Administration (NPRA) in 2009.

At the NPRA, I was employed as an economist working with transport economics issues such as benefit-cost analyses, transport modelling, toll funding, and environmental economics issues. Additionally, I was involved in more complex transport economic issues, such as the transformation of flat-rate toll charges to congestion charging to abate the environmental problems that road traffic causes during congested periods (Aasness 2014), the socioeconomic impacts of the Norwegian government incentives to increase the use of battery electric vehicles (BEVs) as a means of reducing the environmental problems that conventional vehicles (ICEVs) cause, and in the preparation of an annual report to the directors of roads on mitigating climate change in cooperation with other European countries (CEDR 2013).

During my work at the NPRA on the topics named above, I realized that there were certain knowledge gaps that were not yet extensively addressed in the literature on transport economics and planning and that, if adequately addressed, would aid and/or be informative for decision-makers so that sound decisions could be made. Hence, these knowledge gaps became my motivation for research that possibly would lead me to obtain a PhD.

1.2 Research questions and knowledge contributions

The knowledge gaps I identified, for which information was not readily available in the literature and, if obtained, would be knowledge added to scholars, practitioners, and decision-makers, were the following research questions (RQ):

- RQ1: What determines road users' experiences with congestion?
- RQ2: What attitudes do road users have towards transforming a flat rate toll to a congestion charging scheme?
- RQ3: What are the incentives and their adverse effects that led to the increase in BEV usage in Norway?
- RQ4: What are car users' attitudes towards BEV incentives in the 2014-2020 period?

The first two points above were motivated by the fact that Norway has used tolling as a means of financing its road projects. Recently, however, the flat rate tolls in Oslo were transformed to congestion charging schemes where toll rates were increased during rush hours and decreased during nonrush hours. The aim of these changes was to reduce the level of traffic entering the city centres during rush hours and thereby reduce emissions, which are at their highest during congested periods. Despite these changes, the literature has been scant with respect to studies that measured how dissatisfied road users were with congestion and studies that examined the extent to which road users are satisfied/dissatisfied with transforming a flat rate toll to a full-fledged congestion charging scheme. Therefore, the study of these aspects will be a contribution to the literature and will be knowledge added to policymakers, e.g., how road users empirically experience congestion or attitudes towards congestion charging.

Regarding the third knowledge gap, the Norwegian government has implemented several economic incentives in the last decade to reduce GHG emissions from ICEVs. These incentives are meant to induce people to purchase and use BEVs in Norway. While these incentives increase the use of BEVs, they may have some adverse effects that have not been adequately addressed. For instance, if an incentive exempts BEV users from paying tolls, the adverse effect of this incentive is that the income to toll companies that is used to finance road infrastructure projects for all road users will be reduced. Thus, my motivation to study this aspect is to inform the government on adverse effects that are not readily available in the literature.

The fourth knowledge gap is related to the third but from the perspective of the user. It aims to assess road users' attitudes towards the BEV incentives implemented in Oslo for 2014-2020. The results will add knowledge to the literature since only a few similar studies are found in the literature.

To achieve my research objectives as outlined above, I answer the abovementioned RQs addressed in 4 papers. Figure 1.1 illustrates the connections between the RQs and the knowledge contributions from the thesis.

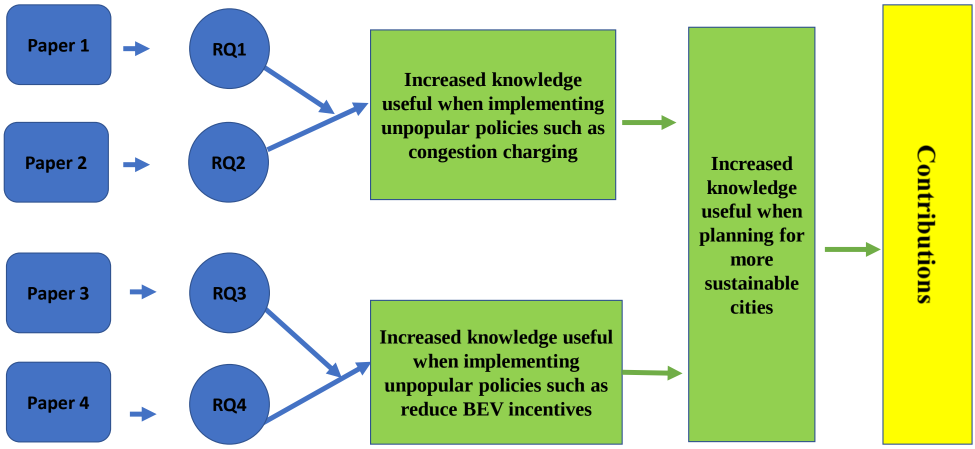

Figure 1.1 Research questions, interrelationship and knowledge contributions

1.3 Structure of the thesis

The remainder of the thesis is structured as follows:

Chapter 2 describes the background and identifies gaps in the literature that this thesis aims to consider. Chapter 3 describes the research design. The method, data sources and data analysis are briefly presented. Moreover, a discussion of the validity of the research method used to address the research questions is presented. Chapter 4 provides a discussion of the results. Chapter 5 provides some implications of the research, limitations, and suggestions for further research. Chapter 6 provides conclusions. Chapter 7 contains references. Finally, chapter 8 contains the four scientific papers.

2 Background

In this section, the topic background is described, leading to the research questions. Subsection 2.1 describes economic theory and illustrates social economic costs. Subsection 2.2 identifies gaps in the literature. Finally, subsection 2.3 describes the case study area.

Urban areas throughout the world experience traffic problems. An increasing number of people now live in urban areas, and urban growth continues globally: In 1960, 34 percent of the world's population lived in cities, while the number increased to 54 percent in 2014 (Atkinson 2019). It is projected to grow to 66 percent in 2050 (Atkinson 2019). The trend in Norway is illustrated in Figure 2.1. The red area shows that the number of people living in urban areas has increased and will continue to increase dramatically from 1950-2050. Therefore, the problems that traffic causes are likely to increase in the future.

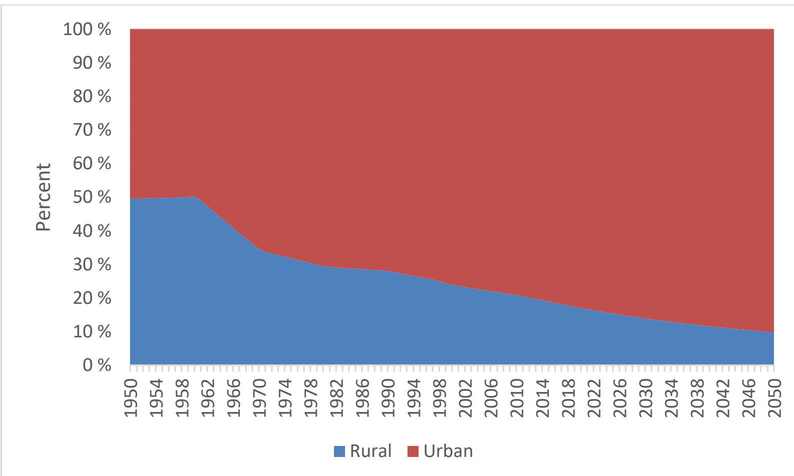

Figure 2.1 Urban and rural population in Norway 1950-2050. Source: World Urbanization Prospects 2018.

Governments worldwide implement different incentives and restrictions to reduce problems caused by traffic, such as congestion, local air and noise pollution, accidents and greenhouse gas emissions, which create externalities. Such restrictions can be, but are not limited to, zone restrictions, congestion charging, road pricing, km pricing, parking restrictions, financial incentives for electrical vehicle users and financial incentives to municipalities in cities (Kuss & Nicholas 2022, Amundsen et al. 2019, Bjerkan et al. 2016). To reduce the externalities mentioned above, the Norwegian government has a goal of zero growth in passenger transport by car (Transport department 2016). One of the measures is the so-called “Urban growth agreements”. Urban growth agreements are a binding cooperation on land use and financing of environmentally friendly transport between the state, county municipalities and municipalities. It should ensure specific land use that promotes environmentally friendly modes of transport. An important premise in agreements is that the government can finance up to fifty percent of investments to promote environmentally friendly transport (Amundsen et al. 2019). The reason for the government to use financial incentives for municipalities in cities is that they have no opportunity to implement restrictions on private cars in cities, and municipalities must implement them themselves. Therefore, introducing financial incentives where municipalities finance up to 50 percent of investments if they invest in more sustainable transport will increase the chance of achieving zero growth in personal cars.

2.1 Economic theory

This subsection describes the economic theory behind why externalities such as congestion and BEV incentives are a problem for society.

The main contribution from this thesis is empirical. However, a theoretical foundation is necessary. The economic theory behind implementing restrictions such as congestion charging and reducing financial incentives for BEV users is that externalities occur. Externalities can be defined as “when the social or economic activities of one (group of) person(s) have an impact on another (group of) person(s) and that impact is not fully accounted or compensated for, by the first (group of) person(s)" (European commission 2019). A typical example of an externality is road congestion. Road congestion occurs when the "demand for their use exceeds their capacity" (Falcocchio & Levinson, 2015). Road congestion can be divided into four externalities. Congestion increases travel time, traffic accidents, environmental pollution and fuel consumption (Qingyu et al. 2007). Hence, by driving in congestion, the driver does not take into account the social costs (such as increased travel time for all the other road users, increased emissions from all the other road users, increased fuel consumption for all the other road users and the increased probability of accidents). Without a congestion cost, the driver only considers the average cost by driving, which gives an equilibrium at point G in Figure 2.2. Figure 2.2 illustrates the effect of implementing congestion charging (Lindsey 2006).

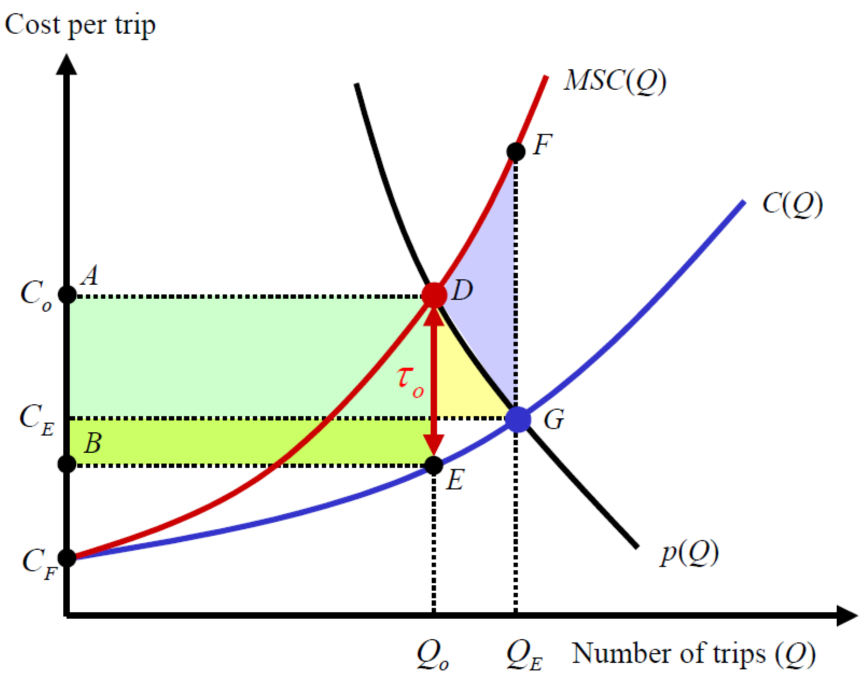

Figure 2.2: Basic road pricing model; source: Lindsey (2006).

Figure 2.2 is based on a model (Lindsey 2006). The assumptions for the model are that the individuals are assumed to be homogenous and take one trip each with only one person per vehicle. Furthermore, it is assumed that these individuals drive on a single road between a common origin and a common destination. The number of trips measured as an hourly flow is plotted along the X-axis, and the cost per trip is plotted along the Y-axis. Costs include vehicle operating costs and the opportunity cost of travel time. When congestion occurs, leading to a slower speed, the average cost of trip C(Q) increases. The demand for trips is represented by p(Q). Equilibrium occurs at the point of intersection, G, without a toll. Q_E trips are taken, each at a cost of C_E. The equilibrium is inefficient from an economic perspective because individuals take no notice of the delay they impose on all the other individuals. The total social cost of Q trips is $TC(Q) = C(Q) * Q$. The social optimum is where the social marginal cost equals the demand curve, $MSC(Q) = \partial TC(Q)/\partial Q = C(Q) + \partial C(Q)/\partial Q * Q = p(Q)$, at interception point D. A reduction in the number of trips from the personal optimum (Q_E) to the social optimum (Q_o) is accomplished by implementing a toll, equal to τ_0; hence, the cost is increased from C_E to C_o. The welfare gain is equal to the triangle DFG, and the total revenue from the toll equals ADEB. Consumer loss is equal to $ADGC_E$. However, it is only the small yellow triangle that is a dead weight loss, and the rest is revenue to the toll company. If the toll revenue can be distributed back to the consumer, as is the case for the Oslo cordon toll system, most of the consumer loss will be distributed back. The revenue from the Oslo toll system is supposed to be used on cycling, walking and public transport investments in addition to maintenance on existing roads.

The same figure illustrates the problems caused by the exemption of tolls for BEV users. BEVs take as much space on the road as ICEVs do, hence contributing as much as ICEVs to congestion. Furthermore, the main intention of the Oslo cordon toll system toll ring is to reduce passenger car traffic, increase accessibility for all groups of road users, reduce greenhouse gas emissions, improve the urban environment and finance road and public transport development. Exemption of the toll gives reduced incentives to reduce passenger car traffic with BEVs, and it reduces toll income. Total revenue from tolls (ADEB) can be thought of as a revenue loss if BEV users do not pay tolls. In addition, exemption of the toll reduces the welfare gain equal to DFG. It is problematic from an economic perspective that income from the Oslo cordon toll system is being reduced because of the exemption of tolls for BEVs.

2.2 Literature

This section describes the gaps in the literature.

In the last two decades, cities such as London, Stockholm, Milan and Gothenburg have had much success in implementing road congestion charging as a means of alleviating the environmental problems that the use of vehicles causes in cities.

Congestion charging has been advocated for by economists for several decades as a way of reducing the travel time costs that a car user imposes on others, which in turn reduces the environmental costs of ICEVs. The current state of the art in the topic of congestion charging can thus be divided into the following categories:

(i) Theoretical studies on the optimality of congestion charging.

(ii) Ex post studies that examine how implemented road pricing/congestion charging is working.

(iii) Attitudinal studies examine road users' attitudes towards congestion charging, in which some researchers investigate attitudes ex ante while others investigate attitudes ex post.

Theoretical studies on the optimality of congestion charging include but are not limited to Vickrey (1963), Arnott et al. (1993) and Lindsey & Verhoef (2000). Ex post studies on the workings of road tolls/road pricing/congestion charging include but are not limited to Eliasson & Jonsson (2011), Börjesson et al. (2016), Small & Gomez-Ibanez (1998), Santos & Bhakar (2006), Eliasson et al. (2009), Odeck & Bråthen (2002) and Odeck & Bråthen (1997 and 2008). Finally, studies that examined attitudes towards road user charges include Jones (1991), Jaensirisak et al. (2005), and Odeck & Kjerkreit (2010).

A general observation from the state of the art, as demonstrated in the literature and a motivation for research on the topic, is that while many studies have investigated diverse aspects of congestion charging, there is little empirical evidence on how road users experience road congestion. If provided, empirical evidence on how road users experience road congestion would expand the literature and inform decision-makers on who to target with information on why congestion is a social problem. Second, the existing state of the art has not examined how road users who were previously subjected to flat rate tolls react in terms of their attitudes towards a transformation to congestion charging, where toll rates are higher during rush hours and lower during nonrush hours. Thus, the information obtained from the first two research questions I explore will add value to the literature on congestion charging. Close to this topic are studies about driver frustrations in congestion (Ye et al. 2013 and Murphy et al. 2016) and about driver stress in congested networks (Sottile et al. 2017). Furthermore, the only paper found that investigates an empirical example when going from a flat rate toll to a congestion charging scheme is Tvinnereim et al. (2020). However, there are several differences between this thesis research and these previous studies. For example, Tvinnereim et al. (2020) focus on geographical differences, but RQ2 in this study focuses on the change in addition to BEV users. Tvinnereim et al. (2020) use the toll system in Bergen

(Norway's second largest city), but RQ2 uses Oslo as a case study where Oslo was named the capital of BEVs in 2014 (Euro Cities 2014). These studies will be referenced in my study.

Regarding the state of the art on the extent to which governments' BEV incentives are effective and how those incentives can contribute to BEV adoption, several studies have investigated this topic. Such studies are divided into

(i) Studies that used sales/market data (including but not limited to Jenn et al. 2018, Sierzchula et al. 2014, and Austmann 2021)

(ii) Studies that used survey data/experimental data to infer the effectiveness and how those incentives can contribute to the adoption of BEVs (including but not limited to Wang et al. 2017, Helveston et al. 2015 and Haustein et al. 2021)

(iii) Studies that specifically looked at how effective Norwegian BEV incentives have been while using either (i) or (ii) above as a point of departure.

The third paper in this thesis belongs to this last group. Several reports and seminar papers in the literature have addressed BEV policy in Norway in general but were not specific to adverse effects. (See Hannisdahl et al. 2013, Figenbaum & Kolbenstvedt 2013, Holtsmark 2012, Holtsmark & Skonhoft 2014, Bjerkan et al. 2016, Figenbaum et al. 2015, Zhang et al. 2016, Deuten et al. 2017 and Figenbaum & Nordbakke 2019). Adverse effects have been analysed in Fridstrøm (2019). However, such a paper was not found when paper 3 was published. The conclusion is thus that the adverse effects of BEV incentives were not adequately addressed in the literature before Paper 3 was published. If this research question is addressed, the information obtained may be informative for decision-makers to design appropriate incentives to increase the purchase and use of BEVs. Perhaps the most related study to the last paper surveyed motorists in New Zealand about their attitudes towards and perceptions of plug-in electric vehicles (BEVS and PHEVs) and the popularity and awareness of the incentives for both plug-in electric vehicles and ICEV users (Broadbent et al. 2021). The results showed that the "strongest barriers [among New Zealand motorists] to plug in electric vehicles purchase were vehicle range, ICEV driver perceptions that plug in electric vehicles are expensive, inconvenience relating to charging and the unknown value proposition of batteries" (Broadbent et al. 2021). Fridstrøm (2019) calculated the external marginal cost of passenger vehicles in Norway. The findings were that the external marginal cost of congestion is the largest cost component of the total marginal costs of passenger vehicles. However, there were no major differences in the marginal external cost between vehicles of different fuel types. As illustrated in Figure 2.3, during rush hour, the fuel tax almost covers the external costs in rural areas but is far below the external costs in urban areas.

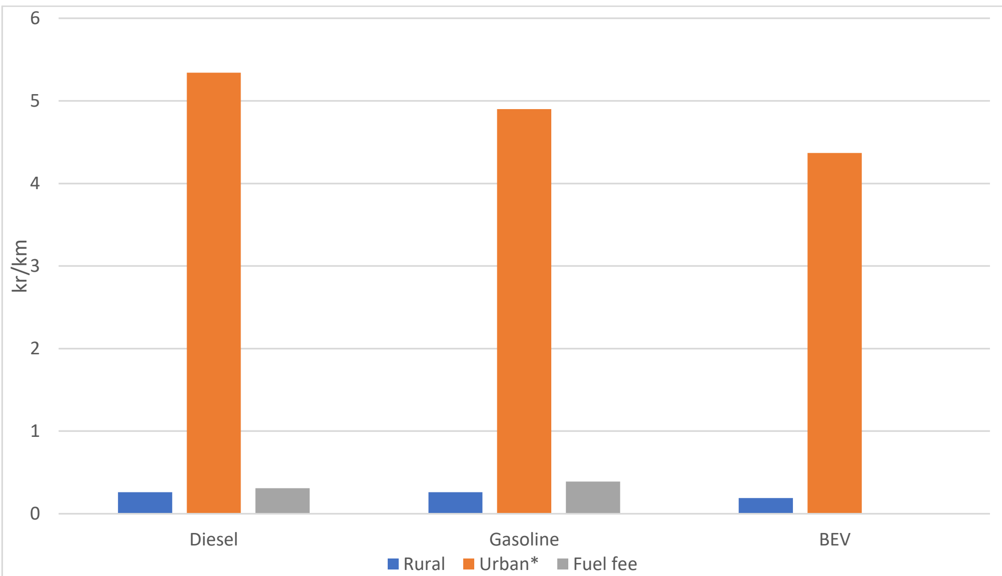

Figure 2.3. Total marginal external costs of passenger car use during rush hour compared with the fuel tax, density and fuel type. *Urban defines with more than 100 000 inhabitants. Source: Fridstrøm (2019).

Section 2.2.1 provides examples of studies in each of the categories of how BEV incentives work in practice and how effective they are. However, car users' attitudes towards BEV incentives, especially where incentives for BEV usage are in place, such as in Norway, have not been adequately studied in the literature.

2.3 Case description

In this section, the geographical context of the thesis is described.

The study area is the larger Oslo area, where Oslo is the capital of Norway.

Figure 2.4: Map of the Oslo area. Source: Oslo package 3 secretariate.

As illustrated with red arrows in the map in Figure 2.4, the larger corridors in and out of Oslo city are the E6 south corridor, E18 west corridor and E6 northeast corridor. The blue lines are the Oslo toll ring in 2017, when congestion charging was implemented. The orange line is the city limit on the western part of Oslo. As already mentioned, an increasing number of people live in urban areas. Over 40% of the Norwegian population lives in the Oslo area and the surrounding county of Viken County (SSB 2021). Figure 2.5 illustrates population changes between 1986 and 2021 in Oslo, Viken (surrounding Oslo) and the neighbouring counties Innlandet and Vestfold and Telemark. The reason to include the neighbouring counties is to illustrate the sharp increase in Oslo and Viken compared to the neighbouring counties.

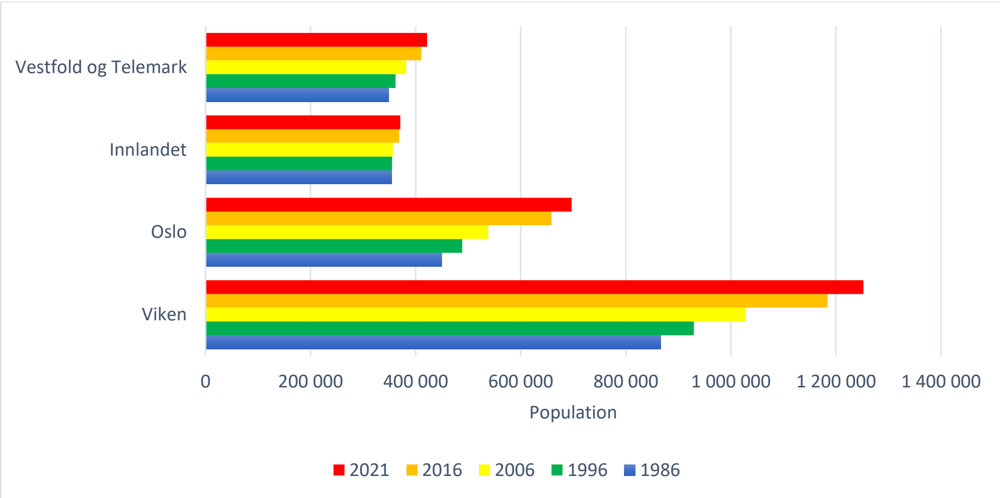

Figure 2.5: Change in population from 1986-2021. Source: SSB (2021)

Population growth was much higher in Viken and Oslo. Congestion problems are therefore more likely to arise in this area. Limited space and high population growth lead to higher prices in Oslo. High housing prices lead to fewer people being able to afford to buy a place to live in Oslo, and more people are moving outside Oslo County but still work in Oslo. Figure 2.6 shows that Oslo has by far the highest cost per square metre in Norway.

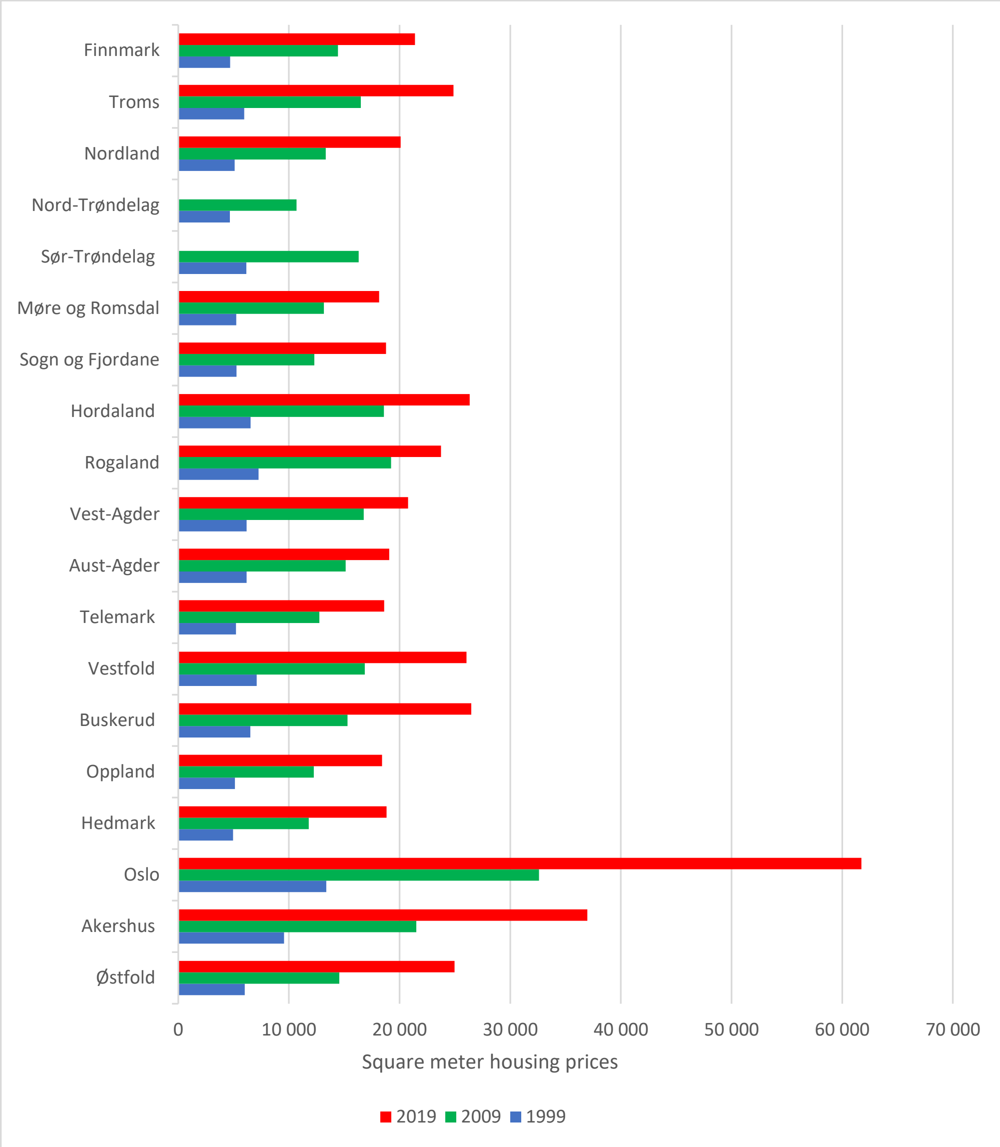

Figure 2.6: Housing price per square meter in Norway, 1999-2019. Source: SSB (2021)

Another characteristic of the research area is that Oslo city transformed its cordon toll ring, which was meant to finance road infrastructure and public transport, to a congestion charging scheme in 2017. The transformation implied higher toll rates during rush hours and lower rates during nonrush hours. The toll charging points remained unchanged. The questionnaire survey used in RQ1 and RQ2 was conducted one month after this conversion.

This study may therefore detect how people familiar with toll charging experience congestion, and their attitudes towards congestion charging would be in the most congested area in Norway.

BEV incentives have been in place for several years and are experienced by road users. Norway is renowned to be ambitious in practicing BEV incentives (Aasness & Odeck 2015, Bjerkan et al. 2016, Figenbaum & Nordbakke 2019). Oslo was named the BEV capital in 2014 (Euro Cities 2014). The reason for the increase is the economic benefits for buying and purchasing BEVs, where one of the most important benefits is the exemption of tolls (Bjerkan et al. 2016, Figenbaum & Nordbakke 2019).

3 Research design

In this section, the research design is described and justified. The data sources, method and data analysis are briefly presented. Moreover, a discussion of the validity of the research method used to address the research questions is presented.

3.1 Data source

The questionnaire survey used to answer RQ1 and RQ2 was distributed in the larger Oslo area in November 2017, one month after the implementation of the congestion charging scheme. The aim was to obtain a representative sample to secure a scientific basis to generalize the findings (Krosnik et al. 2014). To achieve representativeness, we surveyed individuals travelling in the greater Oslo area, mapping at least 500 trips on each of the major corridors in and out of the city of Oslo; individuals travelling to the centre of the city of Oslo; and individuals making other trips. The participants answered various questions about their most recent journey lasting at least ten minutes, which was used as a reference trip. The questionnaire survey contained questions about socioeconomic factors, their trip characteristics, their experience with congestion and their attitudes towards the transformation to congestion charging in accordance with the Likert scale (Joshi et al. 2015). A total of 2563 adults responded. To collect the data, an online survey was conducted. Interest in online surveys has increased for researchers in various disciplines (Wright 2005). Online surveys are cost efficient and can be conducted in a short period of time (Nayak & Narayan 2019 and Ebert et al. 2018). Ebert et al. (2018) compared the costs of conducting an online survey compared to paper invitations and concluded that online surveys are 10 times as cost efficient as paper invitations. Survey research can be defined as “the collection of information from a sample of individuals through their responses to questions" (Ponto 2015). Survey research is often used to describe and explore human behaviour (Ponto 2015). Survey research can be divided into several categories, such as cross-sectional, repeated cross-sectional, panel, and mixed designs (Krosnick et al. 2014). In this thesis, a cross-sectional survey was chosen in papers 1 and 2, where surveys were performed at a single point in time. Although repeated cross-sectional surveys, where multiple independent surveys are collected at two or more points in time, to obtain the time perspective could also have been appropriate, they were too expensive to be conducted as a part of this thesis. However, we had the opportunity to collect the data just after the congestion charging system was implemented in Oslo. Therefore, we had the opportunity to see the short-term ex post attitudes towards the system and the experience with congestion. Panel surveys could also be used where data are collected from the same people at two or more points in time or a combination of them. However, there have been objections to the use of online surveys, especially because some subgroups are often underrepresented. Such subgroups include elderly individuals, low-income persons, less educated individuals, and those lacking high-speed internet access at home. According to Statistics Norway (2020), for the period 2016-2018, 96% of Norwegians used the internet at home. The implication is that online surveys are in line with technological developments, making them a highly reasonable way of reaching a representative sample of Norwegian adults. The interviews were conducted in November 2017, three years before the COVID pandemic that led to shutdown policies that reduced people's possibility of travelling. The sample is therefore representative of normal travel circumstances. The sample comprised 53% women and 47% men. The mean age was 46 years, with a range from 18-91 years old.

To answer RQ3, information available on the websites of Norwegian BEV organizations, such as the Norwegian Electric Vehicle Association (elbil.no), is used. Data on traffic were mainly gathered from the Oslo toll ring company.

The data used in paper 4 are based on an annual survey conducted since 1989. An annual survey has been carried out among the populations of Oslo and Viken (formerly Akershus) about their attitudes towards various aspects of the toll stations. The main purpose of this series of reports and the annual survey is to uncover any behavioural and attitudinal changes over time. Cross-sectional surveys, where multiple independent surveys are used, were collected four times a year to capture any seasonal variations and obtain the time perspective from 2014 – 2020. (NPRA 2020). In this paper, the focus is the new questions implemented in 2014 about attitudes towards BEV incentives. Hence, the questionnaire survey has data for seven different years, collected 4 times a year, with approximately 1000 participants each year. In total, the data set consists of 6363 responses. The data collection was conducted in the form of computer-assisted telephone interviews by professional data collection companies (Norfakta Markedsananlyse AS and Opinion). The sample comprised 49% women and 51% men. The mean age was 51 years, with a range from 18-99 years old. The sample is representative based on age, gender and geography (proportional distribution of respondents from Oslo and Akershus) (NPRA 2020). The main RQs posed in this thesis are defined as what questions; therefore, an appropriate research method is surveys (Yin 2014). However, a combination of surveys and case studies is used in this thesis. Although a survey is used in papers 1, 2 and 4, the city of Oslo is used as a case study for all the papers in the thesis. A case study can be defined as “an empirical inquiry that investigates a contemporary phenomen in depth and within its real -life context” or “ the process of learning about the case and the product of our learning” (Table 5 in Crowe et al. 2011). A case study approach is useful to explore an event or a phenomenon within its real-life context (Crowe et al. 2011). When investigating the RQs for this thesis, Oslo is used as a case study. Several characteristics of Oslo are noted in section 2.3.

3.2 Methodology

Given the data we have and the hypotheses we want to test, the methodological approach we use is the data regression model. A regression model describes the relationship between the response (dependent) variable(s) and one or more explanatory (independent) variables.

The response variables to be explained for RQ1, RQ2, and RQ4, classified in terms of how negative respondents were, are discrete/categorical variables. What distinguishes the categorical response variable from a continuous variable is that it takes on either two (binary or dichotomous) or several levels (Hosmer et al. 2013). Common to RQ1 and RQ2 is that they both have an ordered response variable, and it is possible to rank the response variable from high to low. However, the distance between the categories is unknown (Mehmetoglu & Jakobsen 2017), in contrast to linear regression models such as ordinary least squares regression (OLS) with a continuous variable. A continuous dependent variable is a random variable where the data can take infinitely many values. In OLS, the relationship between a dependent and the independent variables is constant across all values of the continuous independent variable. For each one-unit change in the explanatory variable, there is a corresponding one-unit change in the dependent variable. For models with categorical outcomes, the probability of the outcome for one unit change in one independent variable depends on all the other independent variables. Since the distance between the categories is unknown, it may not be the same distance between categories. For instance, if the response variable is very negative, negative, positive, or very positive, the distance between very positive and positive may not be the same as the distance between positive and negative.

Common for survey research is that the outcome variable is often discrete, taking on two or more levels (Long & Freese 2014). The logistic regression model is the most frequently used regression model for the analysis of these data (Hosmer et al. 2013). There are two main reasons for choosing the logistic distribution. First, from a mathematical point of view, it is a flexible and easily used function. Second, the model gives meaningful estimates of the effect (Hosmer et al. 2013). The specific logistic regression model can be defined in several ways. Either a latent variable model or a nonlinear probability model, each reaches the same form of the model (Long and Freese 2014). The nonlinear probability model can be defined as follows:

$$\pi(x) = \frac{e^{\beta_0+\beta_1 x}}{1+e^{\beta_0+\beta_1 x}} \qquad (1)$$

where $\pi(x) = E(Y/x)$represents the conditional mean of Y given x when the logistic distribution is used. A transformation of $\pi(x)$ is central for logistic regression and is called the logit transformation (Hosmer et al. 2013). The transformation is defined in terms of $\pi(x)$ as

$$g(x) = \ln\left[\frac{\pi(x)}{1-\pi(x)}\right] = \beta_0 + \beta_1 x_1 \qquad (2)$$

The importance of this transformation is that $g(x)$ has many of the desirable properties of a linear regression model. The logit, $g(x)$, is linear in its parameters, may be continuous, and may range from -∞ to +∞, depending on the range of x. There are two main differences between linear regression models and logistic regression models. First, the nature of the relationship between the outcome and the independent variables is different in linear regression and logistic regressions. In linear regression models, the conditional mean $E(Y/x)$ can take on any value as x ranges between -∞ to +∞. In logistic regression with a dichotomous outcome variable, the conditional mean must be greater than or equal to zero and smaller than or equal to one ($0 \leq E(Y/x) \geq 1$). Second, the conditional distribution of the outcome variable differs. In linear regression models, the most common assumption is that ε follows a normal distribution with mean zero and variance that is constant across levels of independent variables. In logistic regressions with dichotomous outcomes, the outcome variable given x can be defined as

$$y = \pi(x) + \varepsilon \qquad (3)$$

Therefore, with a dichotomous outcome, ε can take on two different values, either $\varepsilon = 1 - \pi(x)$ if $y = 1$, with probability $\pi(x)$ or $\varepsilon = -\pi(x)$ if $y = 0$ with probability $1 - \pi(x)$. ε has a distribution with mean zero and variance equal to $\pi(x)[1 - \pi(x)]$. The conditional distribution of the outcome variable follows a binominal distribution with probability given by the conditional mean, $\pi(x)$.

To estimate the unknown parameters β, the maximum likelihood approach is used. This approach maximizes the probability of obtaining the observed data. In this thesis, we have several variations named below.

A logistic regression model was used in RQ1 and RQ2 to identify road users' experience with congestion and attitudes towards congestion charging. Among the logit models, the generalized ordered logit (GOLOGIT) model was used in RQ1, and the ordered logit model (OLOGIT) was used in RQ2. OLOGIT is a version of GOLOGIT. Formally, the model is an extension of the logit model described in equation (1). In equation (1), the outcome variable was dichotomous, but in equation 4, the outcome variable was greater than two.

The probability for any given outcome of category (M) in the OLOGIT model in (4) is (Train 2003, Williams (2006 and 2021), Liu et al 2021):

$$\mathrm{P}(Y_i > j) = g(X\beta) = \frac{\exp\left(\alpha_j + iX_i\beta\right)}{1 + [\exp(\alpha_j + iX_i\beta)]}, \qquad j = 1,2, \ldots, M - 1 \qquad (4)$$

The GOLOGIT model modifies equation 4 above by completely relaxing the proportional odds/parallel assumption (Williams 2016), which was the reason to choose this model for RQ1. It provides the following probability for any given outcome of category (M):

$$P(Y_i > j) = g(X\beta) = \frac{\exp\,(\alpha_j + iX_i\beta_j)}{1 + [\exp(\alpha_j + iX_i\beta_j)]}, \qquad j = 1,2, \dots., M - 1 \tag{5}$$

In Paper 4, we have 3 dependent variables; therefore, a structural equation model with a logistic distribution family was applied since it can estimate the relationship between a number of independent variables and more than one dependent variable (Mehmetoglu & Jakobsen 2017). When the dependent variables are ordered, the generalized structural equation model should be used.

Conditional marginal effects

To facilitate the interpretation of the results, a technique called conditional marginal effects was used in papers 1, 2 and 4. The technique converts the results to probabilities and shows the change in probability. The marginal effect shows each one-step change in the explanatory variable X for all the variables in the model when all the other variables are set at their mean (Mehmetoglu & Jakobsen 2017).

Simple statistics

To examine the adverse effects of the BEV policy and to estimate the external costs to society in the case of Oslo, relatively simple statistical procedures were used. For instance, to calculate the revenue loss for the Oslo toll system, the number of BEVs crossing the toll was multiplied by the toll rates they would have paid. Furthermore, many of the findings of this study were based on comparisons between ICEVs and BEVs of cost data that are readily available from the Norwegian Electric Vehicles Association (Elbil.no).

3.3 Ethical issues

Ethical issues in research have a set of principles to follow, and there is a certain code to follow when collecting data (Bhandari 2022). First, participation should be voluntary. The participants should be able to withdraw from the study any time they like. Second, the participants should be informed of the study purpose, whether there are any risks or benefits when taking part in the study and how long the study will take. In the surveys used in this thesis, all the participants were above 18 years old; hence, we did not need any permission to participate if they accepted participation. Third, all identifying information should be removed. and data should be anonymized according to the European Union General Data Protection Regulation. The data used in this thesis are collected with professional data collecting companies that follow the codes named above (Norstat, Opinion and Norfakta Markedsananlyse AS). Finally, all sources should be cited.

3.4 Contribution of this PhD thesis

Given the gaps in the literature that have been identified in chapter 2.2, my PhD project will contribute to the state of the art in the following ways:

- RQ1 will add to the scarce literature on how road users experience congestion with empirical evidence.
- RQ 2 will add to the literature on road users' attitudes towards congestion charging schemes where road users are already familiar with flat rate toll charges.
- RQ 3 explores the adverse effects of government incentives to induce ICEV users to switch to BEVs. It will be the first state-of-the art paper published internationally in which the aim is to assist governments in considering such policies in learning about the possible adverse effects.
- RQ 4 will add to the literature on the effectiveness of BEV incentives by examining road users' attitudes towards BEV incentives. The political cost of reducing incentives is reduced if people, to a higher extent, seem to accept reducing BEV incentives.
- Congestion and economic BEV incentives are closely related. For example, BEV incentives have some opposing effects by increasing traffic and congestion. At the same time, exemptions and reduced tariffs for BEVs reduce toll revenues and thus undermine financing for public transport, cycling paths and other measures intended to improve the urban environment. Furthermore, the external costs in urban areas during rush hour are almost the same for BEVs and ICEVs. The difference is almost covered by fuel taxes paid for by drivers of ICEVs. Hence, all four papers will add knowledge for policymakers and planners when considering measures to reduce externalities such as congestion in urban areas.

3.5 Paper summaries

The research questions presented in Figure 1 are addressed in four papers. The papers are found in chapter 8. Short summaries of the papers are presented below.

Paper 1: What are the determinants of road users' experiences with congestion: Econometric assessment using ordered response models.

Odeck, J. Aasness, M. A., (2022).

In this paper, factors that determine road users' negative experiences with congestion were investigated based on a questionnaire survey conducted in the Oslo area of Norway. The rationale for this paper is that despite several studies investigating road users' attitudes towards congestion charging, limited studies have investigated how road users experience congestion. If conducted, such an investigation would be useful for policymakers when targeting groups of road users who do not consider congestion to be a social problem with information on why congestion is a social problem. To analyse the questionnaire survey, GOLOGIT is used. Factors found to influence road users' experiences with congestion were as follows: (1) whether they experienced congestion on their reference trip; (2) how often road users undertake trips during congestion; (3) the extent to which road users had potential alternative modes of transport other than car use; (4) education; (5) whether respondents had time commitments at their destinations; (6) travel time used during their journey; (7) how often they experience congestion as a problem; (8) when participants begin to experience discomfort with congestion; and (9) age. The results provide new insight into the factors that determine road users' experience with congestion.

Paper 2: Road users' attitudes when a flat rate cordon toll is transformed to a congestion charging scheme: The case of Oslo, Norway.

Aasness, M. A., & Odeck, J. (2022)

The city of Oslo transformed its cordon toll ring meant to finance road infrastructure and public transport into a congestion charging scheme. The transformation involved higher toll rates during rush hours and lower rates during nonrush hours. The toll charging points remained unchanged. In this paper, road users' attitudes towards such a transformation in the short run are studied. This study adds value to the literature by gathering evidence on the following: (i) overall user attitudes towards the transformation to congestion charging, (ii) determining factors that significantly determine those attitudes, and (iii) given that Oslo is currently the capital city of battery electric vehicles (BEVs), how the attitudes of BEV users differ from those of conventional vehicle users is examined. Limited studies exist on users' attitudes towards such a transformation, and decision-makers do not have a reference on how road users who are used to flat-rate tolls will react should such a transformation into congestion charging occur. A questionnaire survey administered one month after the transformation was used to determine road users' attitudes. The dependent variable in the questionnaire was a 5-point scale ranging from totally disagree with congestion charging to totally agree with congestion charging. Ignoring the ordinality and treating it as nominal, i.e., using a multinomial model, we would fail to use some of the information available. An ordered logistic regression model was used to examine the data. The factors found to influence attitudes towards congestion charging are as follows: willingness to pay, whether the respondents like to drive a car, whether they like trains, age, educational level, whether they have had a negative experience with congestion, whether they agree that they experience less congestion with congestion charging, fuel type and geographic area. The direction of the impact of these factors differs; for instance, a diesel car user had an approximately 15 percentage point higher likelihood of expressing very negative views on congestion charging compared to BEV users. The paper will provide useful insight and implications for planning future transformations of flat-rate toll charges and congestion charging schemes in cities.

Paper 3: The increase of electric vehicle usage in Norway—incentives and adverse effects

Aasness, M. A., & Odeck, J. (2015). The increase of electric vehicle usage in Norway—incentives and adverse effects. European Transport Research Review, 7(4), 34.

In this paper, BEV incentives and their adverse effects were analysed. More specifically, (i) what economic incentives make the purchase and use of BEVs in Norway so attractive to road users, (ii) do these incentives have any adverse effects and, if so, how large are they, and (iii) how does the marginal external cost of BEVs compare to that of conventional vehicles? Method used: The above questions are explored using available data and literature while relating to the city of Oslo as a case study. The cumulative result of multiple economic incentives is that they induce road users to purchase and use BEVs. Perhaps the most serious problem is BEV driver exemption from paying tolls, which has led to a sizable loss of toll revenue. This problem is of particular interest because the Oslo cordon toll system has several purposes. Tolls contribute to the financing of public transport solutions for zero growth in passenger car transport and the transition to BEVs, which results in less congestion and reduces GHG emissions. However, there are also some contradictory effects. For example, BEV incentives will increase traffic and congestion. At the same time, exemptions and reduced tariffs for BEVs reduce toll revenues and thus undermine their contribution to financing public transport, cycling paths and other measures to increase the urban environment. External costs, especially in urban areas during rush hour, are approximately the same for BEVs and ICEVs. The loss of toll revenue is still a problem in Oslo.

Paper 4: Car users' attitudes towards electric vehicle incentives: Empirical evidence in the case of Oslo for the 2014-2020 period

Aasness, M. A, Odeck, J. 2022.

The motivation for this study was to investigate car users' attitudes towards BEV incentives in the period from 2014-2020. The major strengths of the study are that (i) it examines road user attitudes about BEV incentives in greater depth and seeks to address gaps in the literature, (ii) it uses a case study where BEV incentives are in place and are experienced by road users, and (iii) it uses longitudinal data sets to track changes in attitudes across years. Thus, the case study provides an ideal environment to examine road users' attitudes towards BEV incentives while employing a rich data set. Such information provides useful insights, especially for policy makers in countries that are still in the innovator phase with limited incentives to offer. Furthermore, the study provides evidence for the Norwegian government of whether BEV incentives are necessary. In addition, it may be easier to make information campaigns of adverse effects of the incentives for those who have the most positive attitude towards the incentives. Therefore, it may be easier to reduce the incentives with the worst adverse effects. Since the introduction of electric vehicles (BEVs), which do not directly emit carbon dioxide, governments have offered incentives to promote BEV use as a means of reducing carbon emissions. These incentives mainly take the form of purchase rebates, tax exemptions, tax credits, and additional perks that range from access to bus lanes to waivers of toll charges or parking fees and free battery recharges. Overall, these incentives impact road users socioeconomically in the sense that those who choose to use/buy BEVs are economically advantaged by lower operational and travel time costs compared to ICEVs. Intuitively, the economic returns from purchasing and using BEVs should increase their adoption among general car users. Factors affecting these attitudes were studied based on a questionnaire survey covering 6363 respondents in the greater Oslo area. The findings of the study showed that so many good incentives exist that there is an increasing share of Oslo citizens who disagree with the economic benefits. BEV users had a significantly higher likelihood of having a positive attitude towards the incentives than ICEV users. Older citizens had a higher likelihood of having a negative attitude towards the incentives. In Norway, discussions about reducing incentives are already ongoing. The findings of this study can provide valuable information to decision-makers in those discussions. Furthermore, such information would be valuable for other countries considering incentives to promote the purchase and use of BEVs.

3.5.1 Co-authors

The papers presented in this thesis were written in cooperation with my main supervisor James Odeck. Table 1 details how each paper has been co-authored and how I have contributed to each paper.

Table 1. Summary of contribution for each paper and workload.

Paper	Estimated workload	Contribution
Paper 1	50 %	James Odeck: Conceptialization, Methodology, Software, Writing - original draft, Writing – review & editing, Visualization, Supervision. Marie Aasness: Methodology, Software, Writing – review & editing, Data curation, Visualization
Paper 2	80 %	Marie Aasness: Conceptialization, Methodology, Software, Writing - original draft, Data curation, James Odeck: Methodology, Writing – review & editing, Supervision.
Paper 3	70 %	Marie Aasness: Methodology, Software, Writing - original draft, Writing – review & editing, Data curation, Visualization. James Odeck: Conceptialization, Visualization, Methodology, Writing – review & editing, Supervision.
Paper 4	90 %	Marie Aasness: Conceptialization, Methodology, Software, Writing - original draft, Data curation, Visualization. James Odeck: Writing – review & editing, Supervision.

4 Discussion of results

In this section, the research questions are discussed based on the results from the four papers included in this thesis.

4.1 RQ1. What are the determinants of road users' experiences with congestion?

The aim of RQ1 was to gain knowledge on the factors that determine road users' experience with congestion. To address that matter, users' experience was valued on a four-point scale from neutral to very negative. The mean value for the ordinal variable is 2,58; hence, a higher share indicates a negative or very negative experience. The mean value of the dependent variable for each of the four-point scale alternatives is illustrated in Figure 4.1.

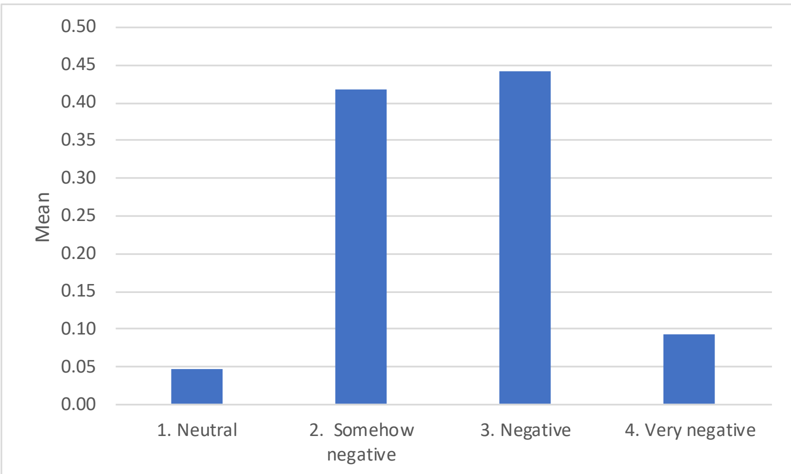

Figure 4.1: Mean value of the dependent variable.

Figure 4.1 illustrates that several state a very negative experience rather than a neutral experience. Furthermore, several state a negative experience rather than somehow negative experience. However, almost half of the participants state a neutral or somehow negative experience. The study confirms that people experience congestion differently. By providing more information to decision makers and planners regarding which factors affect those experiences, it is easier to make information campaigns to change for more sustainable cities. This could, for instance, be those who are most likely to state a negative experience - young people (probably an easy group to be contacted through social media) - on how to change either travel time or travel mode to reduce the probability of congestion. Information to Oslo citizens who have a great supply of public transport, but perhaps they do not know how efficient it could be. This may also be easier after the pandemic, while more people have the possibility of remote work. Or perhaps avoid much congestion, by for instance take morning meeting from home. An interesting result is that those who did not experience congestion on their previous trip are more likely to state a negative experience than those who did experience congestion. Those who actually recall their journey in detail may agree to a larger extent that it was not particularly unpleasant. However, it is also possible that those who did not experience congestion on their previous trip try to avoid settings with congestion to a larger extent. Naturally, the experience with congestion differs; for instance, if they have a time commitment, such as going to the dentist where you have to pay for the appointment anyhow, they are more likely to state a negative experience.

In summary, we found nine different factors affecting experience with congestion, which gives clear signals that people in Oslo experience congestion differently. Although we collected data for the main corridors in Oslo, with different congestion problems, we did not find any significant differences within the corridors.

4.2 RQ2: What are the determinants of road users' attitudes towards congestion charging in cases where road users are used to flat rate toll charges?

The aim of RQ2 was to identify focus groups that are more likely to have a negative attitude towards congestion charging. The effects of congestion charging should be highlighted for the focus group to reduce their negative attitudes towards congestion charging.

Information is an appropriate way to change attitudes towards, for example, tolls (Odeck & Bråthen 2008, Odeck & Kjerkreit 2010, Noordegraaf et al. 2014). Misunderstanding the aim of, for example, congestion charging may lead to the opposite effect (Gaunt et al. 2007). By informing road users that they will experience congestion, they can anticipate and plan their trip accordingly. For example, the Norwegian Public Road Administration implemented "travel time" (NPRA 2021) to inform road users about the state of traffic flow in selected sections. The information is divided into three parts: green section, normal traffic flow; yellow line, some delay (more than 20% longer travel time than normal); and red line, long delay (more than 50% longer travel time than normal). This study confirms the importance of such methods and information to road users. Concerning those who believe in the effect of congestion charging, people who agreed that congestion charging influences congestion were less likely to totally disagree with congestion charging. If citizens obtain information about the traffic reduction estimated to be a 5 percent one year expost (Presterud & Odeck 2018, Oslo package 3 secretariat 2018), perhaps the attitude would change.

The intention for congestion charging in Oslo was to reduce not only congestion but also GHG emissions from vehicles; thus, drivers of vehicles that emit less GHG emissions would be rewarded. Therefore, when congestion charging was implemented, drivers of BEVs were exempted from paying tolls. The results from the questionnaire demonstrate that the drivers of vehicles that are charged the most (diesel users) were more likely to be negative towards congestion charging than BEV users. This result is logical since one of the main reasons for buying BEVs is exemption from paying tolls (Bjerkan et al. 2016, Figenbaum & Nordbakke 2019).

Those with at least two cars were more likely to disagree with congestion charging than those with a maximum of one vehicle. A possible reason for this finding is that there may be a higher probability that individuals with at least two cars drive more and hence are more affected by congestion charging. When congestion charging was implemented in 2017, there were no toll stations in the inner city of Oslo. Those who drove in the inner city were also less likely to totally disagree with congestion charging. Whether this is because they do not pay congestion charging or that they do not need/use their vehicles as much as those outside the inner city is not known. In the inner city, easier access to public transport and shorter distances to travel may favour transport modes other than private vehicles. The coefficients for other corridors were not that different. For example, the E18 west corridor has problems with congestion and delays because of traffic. Travel time can be approximately 15 minutes without congestion and up to 1 hour with congestion.

In terms of individual characteristics, age and education level had an impact on attitudes towards congestion charging. The same characteristics were found in the case of Bergen (Tvinnereim et al. 2020), where a change from a flat rate to a congestion charging scheme was also implemented. Those with a higher education level had significantly less negative attitudes. Moreover, older people had a higher likelihood of totally disagreeing with congestion charging. RQ1 also found that older people were less likely to state a negative experience with congestion. Therefore, it is also reasonable that they do not want to pay too much to avoid congestion. However, whether they are more flexible and could travel more without rush hour is not asked for. Many of the people in that age group still work and were conducted before the pandemic; hence, it was not that easy with remote work.

People who drove more were more likely to totally disagree with congestion charging, probably because they incur more congestion charges. Likewise, those who liked to take the train were more likely to be neutral, agree or totally agree with congestion charging and less likely to totally disagree with congestion charging. The underlying reasons for these findings may be similar—if people take the train, they are less affected by congestion charging.

Few people were willing to pay anything to avoid congestion. Those who were willing to pay at least something were also less likely to totally disagree with congestion charging.

4.3 RQ3: What were the adverse effects of Norwegian incentives to increase the purchase and use of BEVs until 2014?

The aim of RQ3 was to determine the factors that led to the increase in BEVs in Norway until 2014 and to address the potential adverse economic effects of such incentives.

The results showed that the exponential increase in BEV usage in Norway resulted from BEV economic incentives such as exemption from toll charges, exemption from purchase duties, and permission to use transit lanes. Regarding the adverse effects of BEV incentives, we found that the most serious adverse effect was attributable to the exemption from toll charges, which led to the loss of revenues for the toll companies. The adverse effects of exemption from tolls for drivers of BEVs are identified to inform the government, decision-makers and planners on these adverse effects. The annual "revenue loss" is estimated to be 95 million Euros in 2020. Bruvoll et al. (2020) estimated that the yearly revenue loss will be approximately 90 million Euros from 2019-2030. They also estimated an increase in annual passages in the Oslo toll system of 75 million. This finding suggests that the estimated revenue loss in 2014 was considerable.

To calculate the "revenue loss", a doubling of BEVs was assumed until 2017, which was a quite good assumption. The actual share of BEVs is almost the same (see Figure 4.2).

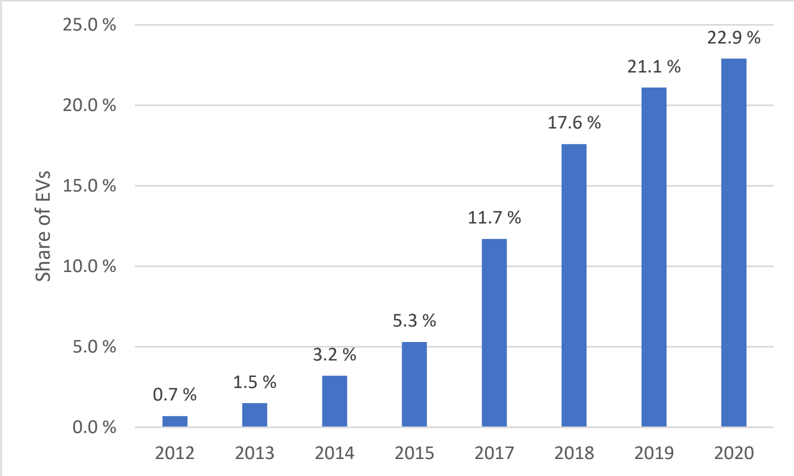

Figure 4.2: Actual share of BEVs of the total crossings in the Oslo toll system

Notably, several aspects are not considered in the calculations. First, in 2017, the Oslo toll system was changed to a congestion charging system. This means a higher price during rush hours and a lower price outside rush hours. Second, at the same time as the congestion charging system was implemented, the environmental aspect was included. In other words, diesel vehicles that emit more local pollution in cities pay more than petrol vehicles. Third, in 2019, BEVs started to pay a symbolic sum, and a so-called "time rule" was implemented. That means that you can drive in and out within an hour and not pay anything more crossing a toll station. A limitation of this study is that it was not considered. However, the meaning was to illustrate how adverse effects such as revenue loss could be without doing anything with the economic benefits for BEV users. Therefore, the focus here is on the share of BEVs, which was the main assumption, and not the actual revenue loss. As mentioned above, a doubling was assumed until 2017. Figure 7 shows that the increase continued after 2017, where a 5% increase was assumed. However, the assumption was based on the fact that the Norwegian would reconsider the incentives in 2017, and many of the incentives are in place at the same time as new luxury BEVs are entering the market. Hence, BEVs can now substitute ICEVs to a larger extent because of battery capacity. Range anxiety is likely to be reduced since many new electrical vehicles have a range of 500 kilometres, and some even exceed 600 kilometres.

4.4 RQ4: What are car users' attitudes towards BEV incentives from 2014-2020?

The aim of RQ4 was to investigate car users' attitudes towards BEV incentives in the period from 2014-2020. As illustrated in the previous section, such incentives lead to adverse effects.

The study intended to help decision-makers identify which factors affect attitudes towards the three economic benefits: free public parking, access to transit lanes without passengers, and exemption from tolls in the larger Oslo area. In Norway, discussions about reducing incentives are already ongoing (Norwegian Electric Car Association 2022, Bruvoll et al. 2022). The results of this study show that there is an increasing proportion of citizens in the larger Oslo area with negative attitudes towards economic benefits. If the government provides clear information on why and how these economic benefits change, it may be easier for citizens to accept these changes. The information derived from this study could also be used to inform those groups of road users who are the most positive towards the incentives about the adverse effects of the incentives (Aasness & Odeck 2015, Bruvoll et al. 2020). Furthermore, such information provides useful insights for policy makers in countries that are still in the innovator phase with limited incentives to offer. The results imply that people living in the larger Oslo are starting to disagree with beneficial BEV incentives, such as those already mentioned. BEV users were significantly less likely to be negative towards the incentives than ICEV users; however, the proportion who disagreed is increasing. Older individuals were more likely to disagree with the incentives, perhaps because older people take longer to adopt new technology. Figure 4.3 illustrates the effect of age and BEVs, controlling for all the other variables. The probability of being negative towards the incentives increases with age, but as expected, older people with a BEV are less likely to be negative than older people without a BEV.

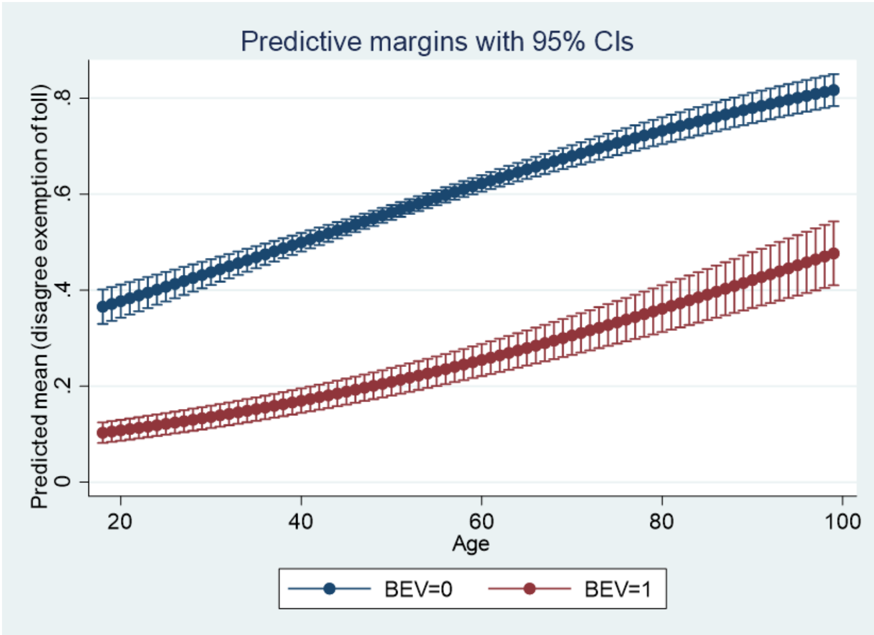

Figure 4.3 The probability of disagreeing with toll exemptions for age fuel type controlled for the other variables.

Those who were satisfied and very satisfied with the cycling path network and the walking facilities had a higher probability of disagreeing with the incentives. Having children also tended to matter; those with children under 15 years old were less likely to be negative towards the incentives.

The proportion of BEV users who disagree with the incentives is also increasing, but it is still much more likely that ICEV users, rather than BEV users, disagree with the benefits.

Environmental concerns matter: those who agree that toll income should finance public transport and that measures should be implemented to reduce pollution, such as environmental speed limits, are more likely to have a positive attitude towards BEV incentives. The results provide new knowledge about car users' attitudes towards BEV incentives from a longitudinal perspective.

5 Implications, limitations, and further research

In this section, a discussion about what knowledge this thesis can provide to decision-makers and planners as well as recommendations for improvements are suggested.

Within constrained public budgets, there is an increasing need for the evaluation and ranking of projects. The simultaneous occurrence of constrained public budgets, congestion problems, and the need to mitigate the effects of climate change is increasing rapidly. The need for good cost–benefit assessment tools is therefore important. In the transportation sector, cost–benefit analysis has been used for decades. Travel time is the largest benefit for most investments in cost–benefit assessments within transport (Börjesson et al. 2014, Mouter 2016). The travel time with severe congestion is almost 3 times as high as that with free-flow traffic. The travel time with moderate congestion is estimated to be almost 1.5 times as high as that with free-flow traffic (Flügel et al. 2020). However, those costs are rarely included in cost–benefit analyses in practice. More advanced models of city problems are needed. This thesis helps to shed light on factors that probably create variation. As shown in this thesis, several factors impact people's attitudes towards congestion charging. These factors could be examined more closely to determine if they should matter for setting optimal congestion charges.

To mitigate the effects of climate change, we need to reduce emissions from human activities. One of the targets is to encourage people to travel more with environmentally friendly modes. This thesis has added knowledge to the literature that decision-makers and planners should consider when planning for a more sustainable transport system.

“Climate change is one of the biggest challenges of our times (EEA 2021). Transports are one of the largest contributors to GHG emissions (Nicholas 2022). A sharp decrease in GHG emissions is necessary to meet the climate change target of being carbon neutral by 2050 (IEA 2021), as illustrated in Figure 5.1.

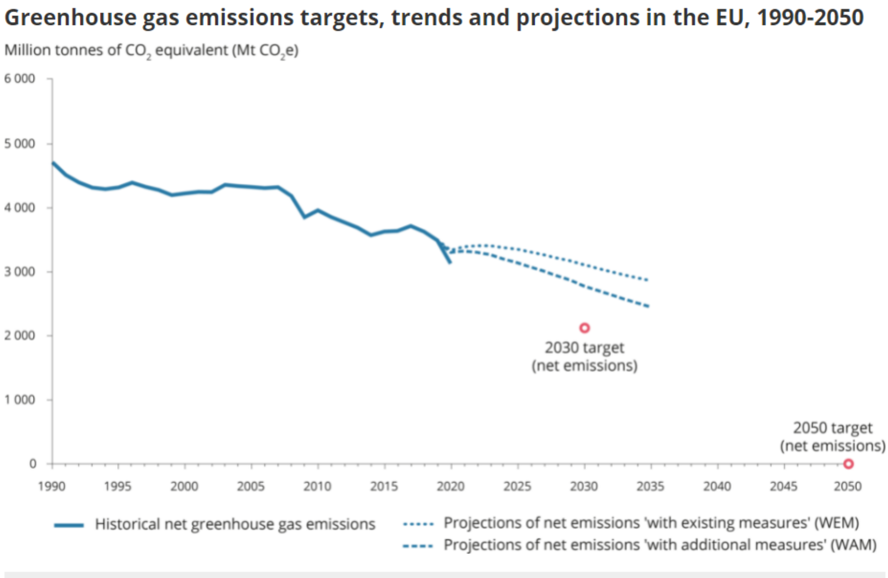

Figure 5.1: GHG emissions targets, trends and projections in the EU, 1990-2050. Source: IEA2021.

The transport sector has also been one of the greatest challenges to achieving national GHG emission targets. In the US between 2009 and 2019, GHG emissions from transport increased more in absolute terms than those from any other sector (EPA 2021). Similar trends are also found in Europe, where GHG emissions in the transport sector steadily increased from 2013-2019. Even more reduction is needed in the future. To achieve the 2030 target of reducing GHG emissions by 55% compared with 1990 levels, twice the average annual reduction observed between 1990 and 2020 is required (EEA 2021). To achieve this target, more people need to use green transport, such as cycling, walking and public transport. This thesis has contributed knowledge to planners and decision-makers on how to implement policy restrictions more easily, such as congestion charging and reduction of BEV incentives. Decision-makers considering implementing congestion charging should inform those groups who are more likely to express negative experiences with congestion and negative attitudes towards congestion charging about the benefits. Otherwise, people are more likely to misunderstand the scheme, as in Edinburgh (Gaunt et al. 2007). By informing citizens about the effects of the implementation of the scheme, there is a higher likelihood of obtaining citizen acceptance. Furthermore, by showing the adverse effects of BEV incentives in Norway and how citizens' attitudes towards those incentives have been in the last few years, decision-makers have a better basis to make sound decisions.

As in many scientific studies, this thesis also has some limitations as follows.

1. The data used in paper 4 were collected in 2020 when COVID-19 was at its peak. However, the questionnaire survey did not address how the COVID-19 pandemic affected respondents' attitudes. This is a limitation because the COVID-19 pandemic at its peak affected travel behaviours, which most likely affected attitudes.
2. This thesis has considered congestion charging and BEV incentives as instruments to reduce congestion. However, several other instruments for reducing congestion exist, e.g., parking restrictions and improved public transport. Thus, the thesis considered only limited instruments for reducing congestion.
3. Where and how often people remotely work, irrespective of the COVID-19 pandemic, was not investigated. A survey among 29 countries found that more people want more flexibility and remote work in the future (World Economic Forum 2021), which will further affect traffic in cities and may lead to less congestion. However, this may also lead to more commuting trips, as house prices outside large cities are less expensive than those in the inner city. If people only need to meet personally at their office 2-3 times a week, it would be less problematic to commute.
4. A potential area for further research is also a more in-depth study on the impact of psychological factors on attitudes and experiences with congestion. Our

questionnaire surveys did not fully account for psychological factors, e.g., the extent to which frustration, annoyance or discomfort influence attitudes and experience.

6 Conclusions

Traffic congestion problems are a fundamental problem in urban areas throughout the world. Governments across the world are implementing several measures to abate the problem. Often, restrictions on personal car use, such as tolls, parking restrictions, and tolls, are measured. However, those restrictions are not popular to implement. Citizens must be provided with good information, as shown in the literature (Odeck & Kjerkreit 2010, Odeck & Bråthen 2002, 2008). This thesis has contributed to several aspects in the literature on the congestion phenomenon and has shown where decision-makers should focus. For instance, the probability of stating a negative experience with congestion depends on different factors. Those who are most likely to state a negative experience may also gain the most from congestion charging. Information campaigns about benefits with such restrictions may make the policy easier to implement. Furthermore, the Norwegian BEV policy has led to several adverse effects. This thesis has illustrated the adverse effects of BEV incentives and Oslo citizens' attitudes towards them. This information can be valuable for decision-makers when considering implementing policies to encourage people to walk, cycle, and take public transport instead of using private cars. If the use of BEVs replaces the use of ICEVs, the policy is a greener alternative. However, if the use of BEVs replaces trips with public transport or walking/cycling, there is a problem with the policy. First, the main income from the Oslo toll system is used on public transport investments and walking and cycling facilities. With reduced income, those investments will be reduced. Second, BEVs take up as much space as ICEVs, especially new luxury BEVs, which are parking at a minimal cost in the city of Oslo, where the supply of other modes of transport is high. Third, urban growth continues globally; hence, externalities with traffic problems will only increase.

The findings of this thesis demonstrate that approximately half of the participants are neutral and somehow negative toward congestion. An important factor influencing this neutrality is whether they experienced congestion on their previous trip. On average, those who did not experience congestion have a higher likelihood of reporting a negative experience with congestion than those who did experience congestion. This indicates that those who recall their journey in detail may agree to a larger extent that it was not particularly unpleasant. However, it is also possible that those who did not experience congestion on their previous trip avoid settings with congestion since they have such a negative experience with congestion. Moreover, the attitude towards congestion charging was investigated so that an information campaign could be implemented to inform focus groups about the benefits of congestion charging. Furthermore, the exemption or reduced toll for BEV users leads to more congestion and reduces income to the Oslo toll system. The revenue is used on measures to obtain a more sustainable city, such as better walking and cycling facilities and public transport investments. This thesis highlights several factors affecting peoples’ attitudes towards those incentives from a longitudinal perspective.

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8 Scientific papers

Paper I

The final published version is available in Research in Transportation
Economics 202Q ;Volum 10Q. s. 1J13.
Published by Elsevier. This is an open access article under the CC BY license.
http://dx.doi.org/10.1016/j.retrec.202Q.101Q23

Paper II

The final published version is available in Research in Transportation Business and Management (RTBM) 2023 ;Volum 50. Published by Elsevier. This is an open access article under the CC BY license.
http://dx.doi.org/10.1016/j.rtbm.2023.100971

Paper III

Eur. Transp. Res. Rev. (2015) 7: 34
DOI 10.1007/s12544-015-0182-4

ORIGINAL PAPER

The increase of electric vehicle usage in Norway—incentives and adverse effects

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Received: 30 December 2014 / Accepted: 22 September 2015 / Published online: 8 October 2015

Abstract
Purpose Norway has been named the "capital" of Electric Vehicles (EVs) because the purchase and use of EVs in Norway has increased tremendously over the last few years. Currently, the fleet of EVs in Norway is the largest per capita in the world. From a transportation research perspective, the questions immediately asked are (i) what economic incentives make the purchase and use of EVs in Norway so attractive to road users; (ii) do these incentives have any adverse effects and, if so, how large are they; and (iii) how does the marginal external cost of EVs compare to that of conventional vehicles.
Method We explore the above questions using available data, the literature and personal observations while relating to the city of Oslo as a case study.
Results We find that the tremendous increase in the use of EVs is the result of multiple economic incentives, such as exemption from toll charges, exemption from purchase duties and permission to use transit lanes that induce road users to purchase and use EVs. The increase in EVs has led to a reduction in CO_2 emissions. However, some of the EV incentives have adverse effects, the most serious of which is the exemption from toll charges, which has led to a sizable loss of toll revenue. We find that the marginal external cost of EVs' road use is approximately the same as that for a conventional vehicle.
Conclusions The incentives for EVs should consider the adverse effects and how electricity is produced; the Norwegian approach should not be followed by other countries without due consideration of these factors.

Keywords Electric vehicle · Norway · Incentives · Adverse effects

This article is part of the Topical Collection on Driving Societal Changes towards an Electro-mobility Future

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1 Introduction

Governments throughout the western world are currently concerned with how to motivate people to start using electric vehicles (EVs). EVs can deliver a more environmentally friendly form of transport while simultaneously reducing dependence on oil. Emissions, e.g., CO_2, NO_x, or particulate matter, can be reduced locally and overall if the efficiency of power generating plants is improved. In addition, the use of EVs may lead to a reduction in noise exposure compared to traditional vehicles. While EVs offer benefits to society, their restrictions, such as a limited travel range or higher prices, have not been accepted by consumers in different parts of the world; thus, their sales volume has been very low.

In Norway, however, the situation with regards to the purchase and use of EVs is quite different from that observed elsewhere in the world. In fact, there is currently EV "fever" in Norway. Tesla S and Nissan Leaf, both EVs, are at the top of car sales statistics in Norway. Figure 1 gives an overview of developments in the purchase of EVs in Norway. As it is clear from the figure, the purchase of EVs has almost doubled annually since 2012, and this trend is expected to continue, since the government still encourages the use of EVs. It is these observations that have given Norway its status as the capital

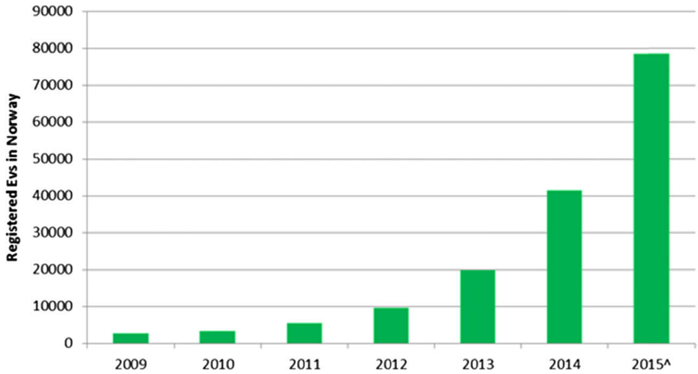

Fig. 1 Registered EVs in Norway. Source. http://www.gronnbil.no/statistikk?lang=en_US). ^Estimated for 2015

of EVs and that demonstrate the need for further study into the drivers behind this increase, which we investigate in this paper.

These formidable increases in the purchase and use of EVs have been prevalent in the city of Oslo to such an extent that Oslo has been named the electric vehicle capital of the world [1]. This is particularly interesting because Oslo has a cordon toll system, where motorists pay tolls yet the impact of increasing EV usage given that one incentive for purchase is exempting EVs from tolls has not been previously studied in the literature. From a transportation research perspective, the prevailing situation in Norway, and in Oslo in particular, with regards to the purchase and use of EVs raises several questions e.g., whether the incentives to EV purchase and use are economically effective and efficient. In this paper we examine such questions as follows: we (1) address the incentives behind the observed developments and how these have been received by travelers in Oslo case study and, (2) examine and broadly assess the adverse effects caused by the incentives in the case of the Oslo toll ring.

The rest of the paper is organized as follows. Section 2 is brief literature review of EV policy in Norway. Section 3 gives a short description of the methodology and data used. Section 4 presents EV incentives and how they have worked in Norway. Section 5 discusses the adverse effects of the incentives. Concluding remarks are given in Section 6.

2 Literature review

There are several reports and seminar papers in the literature that have addressed EV policy in Norway. Hannisdahl et al. [4] addressed the future of EVs in Norway and lessons learnt to date. They observed that it is not the car producing nations such as Sweden and Germany that have engaged aggressively with EVs. Instead, Norway has led the rest of the pack in terms of both implementing policy incentives and increasing the number of EVs on the road compared to its total car population. These authors observed that the EV technology was good enough and that a set of incentives was necessary to achieving successful expansion of EV usage. Figenbaum and Kolbenstvedt [2] in their research report considered electromobility with regards to the experience in Norway. Their major finding was that the Norwegian EV policy, with its many incentives and the establishment of Transnova (a body giving financial support to charging facilities), has reduced the barriers for E-mobility, i.e., the purchase and use of EVs. They further observed that EV users are typically men in multi-car households located in the largest city suburbs. In addition to these studies, there are a plethora of websites that both monitor and encourage the use of EVs in Norway and abroad; hence they often produce short articles about EVs in Norway; see, for instance, *Gronnbil.no*; *elbil.no* and; *Eurocitie.eu*.

Another interesting issue in the literature is a disagreement on whether Norwegian EV policy works as intended. Holtsmark [5] addresses this question. He concludes that EV owners should not be exempted from paying for road use, parking fees and the energy they use and that it is difficult to see why EVs should have access to bus lanes. Figenbaum and Kolbenstvedt [2], however, disagrees with Holtsmark [5] and concludes that the Norwegian EV policy does work as intended. In another critical study of Norwegian EV policy, Holtsmark and Skonhoft [6] investigated the Norwegian support and subsidy policy for EVs. They found that the usage of EVs implies very low costs to users on the margin and that it leads more driving at the expense of public transport and cycling. Moreover, because most EVs have a short driving range, the policy gives households incentives to purchase a second car, again stimulating the use of private cars instead of public transport and cycling. Their conclusion is that the Norwegian EV policy should be terminated as soon as possible and that this policy should not be implemented by other countries. Others dispute these conclusions from the perspective of reaching climatic goals. For instance, Figenbaum and Kolbenstvedt [2] find that not only Norwegian but also European climatic goals for average emissions from new cars can be reached with increased electro-mobility i.e., extensive use of EVs. The dispute among these Norwegian authors can be further explored by examining the international literature addressing similar situations in countries comparable to Norway such as Sweden. Hultkratz and Liu [7] make a before–after comparison that indicates that the impact of the road toll in Stockholm on traffic volumes was smaller when the system was re-opened in 2007 compared to the effect during the trial period in 2006. They found that the growth in the share of exempted "green" cars and the decision to make charges deductible from income taxes would considerably reduce the positive welfare effect of the toll at the time when the "green" car exemption was abolished. What can be deduced from the literature is that socio-economically, Norway's EV policy is not optimal, but may be the way forward to meet climate change.

3 Methodology and data

The nature of this study implies a methodological approach that combines the analysis of source data and the inherent incentives in the Norwegian EV policy, and relatively simple statistical procedures to examine the adverse effects of those incentives with respect to the Oslo toll ring case study. Figure 2 illustrates the effects of those incentives and their data sources.

To describe the incentives behind the observed increase in the purchase and use of EVs, we simply use information available on Norwegian EV organizations' websites such as the Norwegian Electric Vehicle Association (elbil.no) and the Norwegian Green Vehicle organization (gronnbil.no). Further, we supplement this information with previous studies such as Figenbaum and Kolbenstvedt [2].

To examine the adverse effects of the EV policy and to estimate the external costs to society in the case of Oslo, we use relatively simple statistical procedures. For instance, to calculate the revenue loss for the Oslo toll ring, we multiply the number of EVs crossing the toll by the toll rates they would have paid. Furthermore much of the message that this paper conveys is obtained by comparing data on costs between conventional vehicles and EVs that is readily available from the Norwegian Electric Vehicles Association (Elbil.no).

Data on traffic were mainly gathered from the Oslo toll ring company. The data included toll rates and the number of vehicles crossing the tolls divided by different vehicle categories, e.g., EVs, non-EVs, heavy passenger vehicles, etc. Data on congestion costs was taken from Rekdahl et al. [11]. These costs were then multiplied by the number of EVs in the toll ring to derive the external cost of EVs. Data on CO2 emissions were taken from the NPRA's handbook for impact assessment.

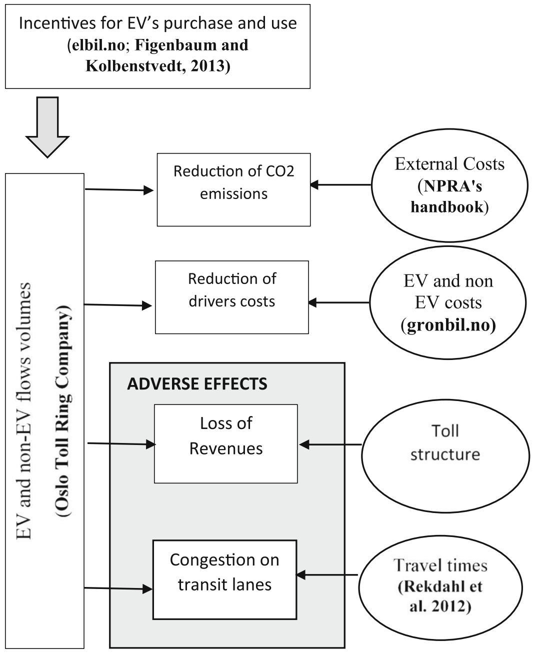

Fig. 2 Illustrating the effects of EV incentives and their data sources

4 Benefits of incentives to purchase and use EVs in Norway

The Norwegian EV incentive scheme has gradually developed over the years and dates back to 1990, when the government exempted EVs from import and value added tax on a trial basis. This exemption became permanent in 1996. In the following year, 1997, EVs were exempted from road tolls in Norway. From this point on, a host of incentives have been implemented including exemption from using transit lanes, reduced company car tax, and exemption from car ferry fares. The overall goal of these EV incentives has been to bring the purchase and use of EVs up to or beyond par with that for similar conventional vehicles in Norway. An objective of the government has been to achieve a proportion for the EV fleet in the Norwegian road network of approximately 10 % by 2020. A list of the incentives in place to meet these government objectives and the time that they became permanent is shown in Table 1 below.

4.1 Savings for EV users

To understand how powerful the above incentives are, consider first the exemption from taxes. Conventional vehicles are heavily taxed in Norway compared other comparable European countries. Import duties on vehicles are charged according to their weight, CO2 emissions, motor effects and

Table 1 The implemented EV incentives

Incentive	Trial-period	Permanent year
Temporary Exemption from on-off registration tax	1990–1995	1996
Exemption from annual vehicle tax	–	1996
Exemption from road tolls	–	1997
Exemption from parking fees on municipal owned parking facilties	–	1999
Reduced company car tax	–	2000
Exemption from VAT		2001
Temporary use of transit lanes	2003–2005	2005
Parmanent use of transit lanes	–	2005
Further reduction in company car tax		2009
Exemptionion from paying car ferry fees	–	2009

NOx emissions. In addition, there is an additional Valued Added Tax (VAT) of 25 % of the purchase value. EVs are completely exempted from these import duties (taxes) and the VAT; see Table 1. The impact of these tax exemptions is that the total cost of vehicle ownership for EVs generally compares favorably with that of conventional vehicles.

According to the government program, the current tax benefits for the purchase and use of EVs will be sustained until the year 2017, as long as the number of EVs in road traffic does not exceed 50 000 vehicles. Perhaps because of this limit, the last 3 years have seen an explosion in the purchase and use of EVs in Norway, as observed in Fig. 1; consumers are striving to enjoy the tax benefits of EVs while they still can, and they are not necessarily being environmentally friendly. With the entry of Tesla in the EV market and the emerging battery technology that allows EVs to continually cover longer distances, the total cost of owning an EV is also becoming favorable in terms of distance covered compared to conventional vehicles.

Yet another powerful EV incentive shown in Table 1 is related to cities and thus may be another factor in Oslo's status as the capital city of EVs. EVs are allowed to access transit lanes and, in addition, are exempted from paying road tolls, which are very common in the larger cities of Norway. The use of transit lanes is convenient and readily converts to time savings, especially during rush hour. Because time saved is equivalent to money, this too is an economic benefit. Adding these benefits to the exemption of road tolls, the economic benefits of owning and using EVs represents a formidable cost savings that further induces the purchase and use of EVs in cities.

There are other additional powerful economic incentives reported in Table 1 that encourage the purchase and use of EVs within and outside of cities in Norway. These are as follows: (1) EVs are exempted from paying the numerous car ferry fares on the national road network, (2) EVs have only a 50 % taxable benefit if used as a company car, (3) EVs are exempted from parking fees in all municipality-owned parking spaces, and (4) in municipality owned parking spaces, battery charging is free.

From the discussion above, it is quite clear that the sole incentive behind the formidable increase in the purchase and use of EVs in Norway is economic motivations, whereby EV road transport users (EV car users) obtain financial gains that would not be possible with the use of a conventional vehicle.

This is confirmed by a comparison between users' attitudes towards purchasing an EV in Norway with Sweden and Denmark, where such benefits are not available. Figure 3, shows results from a survey by Michelin [9], asking about the main reasons for buying an electric car including the price of EVs compared to conventional vehicles, differences in taxes, whether or not free parking was available for EVs, etc.

The responses are revealing and are in accordance with the EV incentives in Norway: Norwegian respondents would, more than their Scandinavian counterparts, consider purchasing an EV because overall costs such as purchase price, taxes, parking, and tolls are low or equal to zero. This enforces our earlier observation that EVs are purchased and used because of the incentives put in place by the government and economic motivations.

To underline the observations above with regards to the available EV incentives in Norway, the operational cost of using an EV is compared to that of using a conventional vehicle through a 5-year period in Table 2.

Based on Table 2, consider a Norwegian vehicle user as a rational consumer who wants to save on the operational costs of using his vehicle. Per year, the EV user saves 3 275 euros: 273 euros monthly and 16 375 over a 5-year period. This is a large amount of savings that certainly encourages Norwegians to buy and use in EVs, especially in cities with scarce parking spaces and costly road tolls. Finally, consider a Norwegian study conducted in July 2014 to infer why Norwegians buy EVs. Figure 4 summarizes the results of that study.

Figure 4 confirms the results in Table 2 to the extent that the main reason for buying EVs is that they are cheaper to purchase and use compared to conventional vehicles. From these

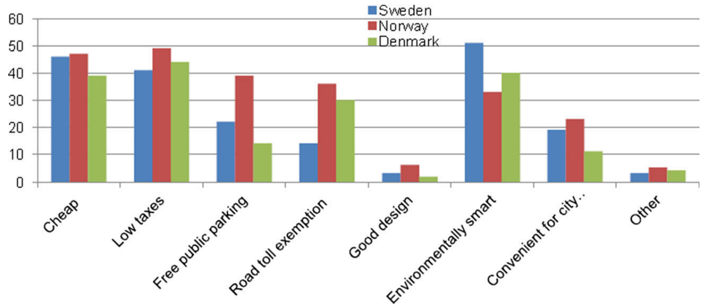

Fig. 3 Reasons for wanting to buy an electric car at next vehicle purchase in Sweden, Denmark and Norway. Source: Michelin [9]

results, we conclude that economic incentives have led to the observed explosion of EV purchase and use in Norway.

4.2 External cost reductions

Incentives to use EV can have also a positive effect in terms of greenhouse gas emissions. By considering the CO2 emission by type of vehicle multiplied by the cost of CO2 per ton emitted according the Norwegian Handbook for impact assessment, the gains of changing from a conventional vehicle to an EV can be derived. Table 3 provides such a calculation; data for emissions by different vehicles were obtained from ofvas.no.

As is evident from Table 3, moving from a conventional vehicle to an EV represents an average cost savings in terms of CO2 emissions. Note the low cost savings from moving from an Opel Ampera to an EV (Nissan Leaf); this is because Opel Ampera is plug-in hybrid and thus does not emit as much as a conventional vehicle such as the Volvo V60. Further note that these costs are per km; to derive the cost per year for each car, the figures must be multiplied by the average distance covered, which is assumed to be 13,300 per year. For instance, the per year CO2 cost for Volvo V40 is 13,300*0.0024 = 32 Euro. The last column of Table 3 shows the estimated annual savings for 2015.

A caution is now necessary with regards to the potential reduction in CO2 emissions by EVs. This reduction depends on how the electricity used in EVs is generated. In areas where coal dominates in the production of electricity, such as China, EVs perform more poorly than the most fuel-efficient gasoline cars; see, for instance, Ji et al. [8] and Holtsmark [5]. Therefore, the Norwegian strategy for EVs should not be implemented by other countries without considering the main source of electricity production. For Norway, the strategy is reasonable in this respect because electricity is produced through hydropower.

Marginal external costs—or the negative externalities of road transport—refer to the costs that vehicles inflict on other agents or on the environment. Typically, such external costs include air pollution, noise, congestion, accidents, infrastructure damage (wear), operations and, of course, CO2 or greenhouse emissions.

It is often difficult to quantify all of the elements of marginal external costs for vehicles because such costs vary by, e.g., vehicle type, where the transportation occurs, and the geographic position of vehicles. However, in many European countries, attempts are often made to

Table 2 Comparing the operational cost of an EV and a conventional vehicle through a 5-year period (source gronnbil.no period)

Values in Euros (1 Euro = 8.8 NOK 2015)

Cost	Nissan LEAF	VAT share	Conventional vehicle	VAT share	Difference
Loss of value	12 516	0	13 091	2 618	−575
Financing	3 830	0	5 182	0	−1 351
Annual tax	230	0	1 639	0	−1 409
Maintenance	2 273	455	2 614	523	−341
Energy	1 705	341	8 949	1 790	−7 244
Parking	0	0	1 364	2 727	−1 364
Road tolls	0	0	4 091	0	−4 091
Sum	20 554	795	36 929	7 658	−16 375
Per year	4 111	159	7 386	1 532	−3 275
Per month	343	13	615	128	−273

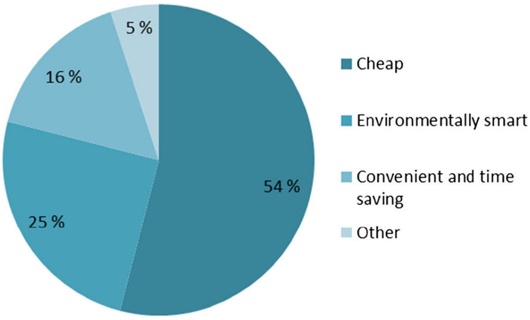

Fig. 4 Main reasons for buying an EV. Source: elbil.no

derive such marginal external costs per kilometer driven and by vehicle type. In the case of Norway, such derivation was recently made by Thune-Larsen et al. [13]. In that report, however, EVs were not included because the calculation of the marginal cost of CO2 was not possible at the time. The report concluded that the marginal external cost for EVs would not be too different from that for conventional vehicles because the marginal external cost of CO2 is expected to be small. In Table 4, we report the results from Thune-Larsen et al. [13].

As the table shows, most of these marginal external costs will also be caused by EVs. For instance, accidents are by far the largest component of marginal external costs, and there is no reason to believe that EVs are less prone to accidents compared to their conventional counterparts. In fact, due to the noiseless characteristic of an EV, some believe that EVs are more prone to accidents involving pedestrians and especially those who are blind, visually and hearing impaired. Therefore, we believe that the marginal external costs of EVs are almost the same as those of conventional vehicles; our calculation for CO2 cost per km gave a value of 0.0024 Euro, which should be added in the table above for the conventional vehicle. However, this is a small value and barely has an effect on the sum of the marginal external costs.

Table 3 Marginal external cost per km with regards to CO2. Source: ofvas.no and SINTEF [12]. (*1Euro = 8.8NOK 2015*)

	g/km	Cost/km	Average cost per car per year	Annual savings 2015[a]
Nissan Leaf	0	0	0	0
Opel Ampera	27	0.0006	9	671,682
Volvo V40	101	0.0024	32	2,512,587
VW Golf	114	0.0027	36	2,835,989
Volvo V60	118	0.0028	37	2,935,497

[a] Estimated number of EVs

5 The adverse effects of EV incentives

The Norwegian EV incentive was initiated to promote the use of alternative fuels and more environmentally friendly technology. To this end, the incentives must be regarded as highly successful in the sense that they have led to the increased purchase and use of EVs in Norway and hence have led to a reduction in greenhouse gas emissions. From this and strictly speaking, the only economically efficient incentive to achieve greenhouse gas reduction should be the gasoline tax, which is presumably set to account for emissions ([10]:8). However, because EVs do not consume gasoline and hence are already exempted from gasoline taxes, exemptions from purchase duties may be regarded as just enough to induce their use. All other forms of incentives, such as in the Norwegian case, have severe adverse effects as follows:

- *Exemption from tolls*. Tolls are meant to finance road infrastructure, which is needed by all types of vehicles including EVs. Exempting EVs from tolls has an adverse effect because it reduces toll income, leading to the insufficient and untimely supply of road infrastructure; it is counter-intuitive. The same argument can be used against exemptions from paying for ferry services.
- *Exemption from parking fees*. Parking fees are meant to reflect the alternative cost of parking spaces. EVs occupy parking spaces just like any other vehicle and, hence, should pay for their use of the parking space. Free parking for EVs amounts to economic loss; the incentive is hence an adverse effect.
- *Use of transit lanes*. Transit lanes are reserved for public transport in urban areas as a means of encouraging the use of this transport. All other users of transit lanes, especially during rush hour, will lead to adverse effects in terms of congesting transit lanes, incurring additional travel costs for public transport users.

Below, we illustrate the magnitudes of some of these adverse effects.

5.1 The study case of Oslo toll ring

The adverse effects of EV incentives discussed above can be elaborated by using observations from the Oslo toll ring. Consider, first, the use of transit lanes by EVs. Figure 5 shows the percentage delay in travel time on transit lanes by week of the year and number of EVs on two road segments along route E18 in the Oslo region. It is clear from the figure that the travel time on transit lanes has increased and is proportional to the increase in EVs using transit lanes; in week 10, the travel time in transit increased by a formidable 15 and 30 %, respectively, for the two road segments from 2013 to 2015. For the 90th percentiles, i.e., the point below which 90 % of the

Table 4 Marginal external costs (Euro) in Norway without CO2 (source: Thune-Larsen et al. [13]) (*1Euro = 8,8NOK 2015*)

	Air pollution	Noise	Congestion	Accidents	Infstrastructure damage	Operations	Sum
Petrol	0.01	0.00	0.01	0.04	0.00	0.01	0.06
Diesel	0.02	0.00	0.01	0.06	0.01	0.01	0.11
LPG	0.01	0.00	0.01	0.04	0.00	0.01	0.07
CNG	0.07	0.01	0.04	0.04	0.03	0.01	0.19

observations fall, the travel time delay is even higher, as it has increased by 40 and 50 %, respectively, in week 10 from 2013 to 2015.

This clearly illustrates that allowing EVs to use transit lanes has an adverse effect on road-based public transport.

Next, consider the loss of toll revenues as a result of EVs being exempted from road tolls in the case of Oslo. The current Oslo toll ring system was implemented in 1990 to generate funds for road investments in the larger Oslo area. Currently, approximately 60 % of toll income is being used for investments and for the maintenance of public transport. The use of a large share of toll income on public transport may be seen as strategy to induce people to use public transport. It follows then that if EVs are exempted from paying tolls, toll revenue from the toll ring will decrease.

We estimated the expected revenue loss for the 2012–2020 period. We assumed that the number of EVs passing toll points will continue to double, i.e., increase by 100 % annually until 2017. After this point, the increase is expected to be less than double because we expect the government to remove some of the adverse incentives in 2017, leading to fewer people being willing to purchase EVs. Revenue loss in year *t* (RL_t) is calculated by multiplying the number of EVs (EV_t) with the toll price (p_t):

$$RL_t = EV_t \times p_t \quad (1)$$

Using the current toll price of 30 NOK, the calculated revenue loss in the year 2012 was

$$RL_{2012} = EV_{2012} {*} p_{2012} = 814047{*}30 = 24\,421\,410 \quad \text{NOK} = 2775160 \quad \text{Euro} \quad (2)$$

Table 5 shows the annual revenue loss for the period 2012–2013 and the annual expected revenue loss for the period 2014–2020. It is clear from the table that exempting EVs from paying tolls leads to large revenue losses, which for the year 2012 was at 2,7 million Euro and which is expected to be a formidable 95 million Euro for the year 2020; based on the assumptions discussed above.

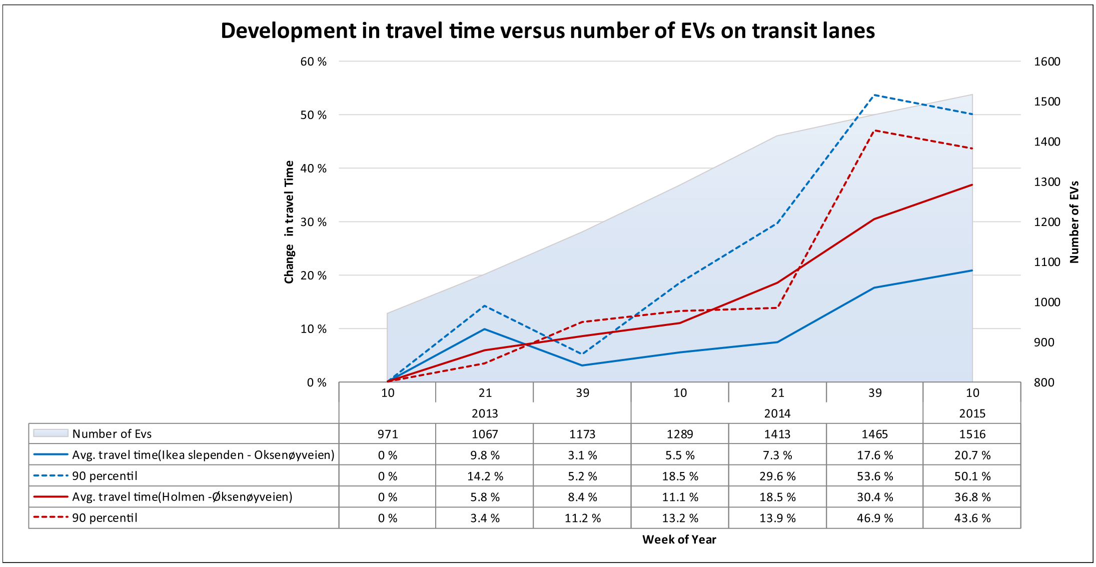

Fig. 5 The adverse effect of EV incentives on travel time in transit lanes (source: Unpublished traffic counts, Norwegian Public Roads Administration (This data is available on request to the authors.) (vegvesen.no))

Table 5 Revenue loss and expected revenue loss. (*1Euro = 8.8NOK 2015*)

	Euro in Mill
Annual revenue loss 2012–2013	
2012	2,7
2013	5,7
Annual expected revenue loss 2014–2020	
2014	11,3
2015	22,6
2016	45,2
2017	90,5
2020	95

It should be here noted that we are not the first to note the danger of these incentives. For instance, Halvorsen and Frøyen [3] noted that there is good reason to question whether maintaining these incentives in the form they have today is desirable for the urban transport situation and land use in the long term. To this, we add that the adverse effects of the Norwegian EV incentives are so many and so large that any country wishing to encourage the use of EVs should not follow them without care.

6 Concluding remarks

The objective of this paper has been to explore the reasons behind the tremendous increase of EVs in Norway that has led Norway to be the number 1 country for EVs. We find that the Norwegian government has used a wide range of economic incentives that have made EVs much cheaper to purchase and use. Among the incentives are exemptions from taxes, toll charges, parking fees and access to transit lanes. Translated into money, these incentives are a huge savings and naturally have induced Norwegians to buy and use EVs in large numbers. We also find that many of these incentives have some unintended effects. For instance, exemption from toll payments has resulted in a reduction in toll revenues, and access to transit lanes has resulted in congestion on those lanes, leading to increased travel time for public transport users. We note and illustrate why such types of incentives should not be given to EV users. Furthermore, the ability of EVs to reduce greenhouse gas emissions depends on how electricity is produced. Our conclusions are therefore that the incentives have helped increase the number of EVs and, as a consequence, reduced greenhouse gas emissions. However, we warn that the Norwegian incentives have led to adverse effects and should not be copied by other countries; it also matters how electricity, which is fuel for EVs, is produced—only hydropower produced electricity, as in Norway, offers a positive impact on greenhouse gas emissions.

Acknowledgments We thank Professor Pierluigi Coppola at the University of Rome Tor Vergata for very useful comments while writing this paper. Any shortcomings are however, ours. We also thank the Norwegian Public Roads Administration for sponsoring this study.

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Paper IV

Research in Transportation Economics 97 (2023) 101262

Contents lists available at ScienceDirect

Research in Transportation Economics

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

Research paper

Road users' attitudes towards electric vehicle incentives: Empirical evidence from Oslo in 2014–2020

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ARTICLE INFO

JEL classification:
R4

Keywords:
Electric vehicle incentives
User attitudes
Longitudinal perspective

ABSTRACT

This paper examines participant attitudes towards battery electric vehicle (BEV) incentives. Our case study was conducted in the greater Oslo area. Oslo has ranked as the world capital of BEV usage since 2014. The Norwegian government currently leads the comprehensive use of BEV incentives to decarbonize road transport. The data set is from a questionnaire survey conducted annually between 2014 and 2020. A total of 6363 individuals divided equally into annual random samples were asked to express their attitudes towards the different BEV incentives in place in each year. Participants were aged 18 or older and were living in the larger Oslo area. Professional data collection companies used computer-assisted telephone interviews to conduct the survey. Generalized structural equation modelling (GSEM) was used to analyse the data. The sample was 49% women and 51% men, with a mean age of 51 years, ranging from 18 to 99 years old. People in greater Oslo increasingly disagree each year with beneficial BEV incentives such as toll exemptions, access to bus lanes without passengers and free public parking. However, internal combustion engine vehicle (ICEV) users are more likely to disagree than BEV users. The results provide new knowledge about attitudes towards BEV incentives from a longitudinal perspective.

1. Introduction

Among the European Union's associated members, road transportation accounts for 28.5% of final energy consumption and approximately 20% of total greenhouse gas emissions (European Environment Agency (EEA) 2020). Similar figures are found for the global road transportation sector (European Commission, 2022)). The road transportation sector has a relatively high percentage of energy use and consequently high greenhouse gas emissions. Governments across the globe have in the last decade looked for potential mitigation policies to reduce greenhouse gas emissions from road transport. Since the introduction of battery electric vehicles (BEVs), governments have offered incentives to promote BEV use as a means of reducing carbon emissions. These incentives mainly take the form of fiscal incentives such as reduced purchase price/yearly cost, direct subsidies such as reduced variable costs and user privileges such as reduced time costs or other relative advantages (see Table 1). Overall, these incentives impact road users socioeconomically by providing lower operational and travel time costs for their vehicle usage. Intuitively, the economic returns from purchasing and using BEVs compared to those from internal combustion engine vehicles (ICEVs) should increase BEV adoption among general car users. This seems to have been the case in Norway, where the share of BEVs in new passenger car registrations is by far the highest in the world. Toll exemptions seem to be one of the most important incentives (Aasness & Odeck, 2015; Bjerkan et al., 2016; Figenbaum & Nordbakke, 2019). The global top rankings of countries with the highest new BEV registrations are Norway (72%), followed by Sweden (45%) and the Netherlands (30%) (IEA, 2022), due to ambitious governmental support programs. By comparing the two top ranking countries, it is easier to understand the gap between them. Due to tax incentives to guide vehicle purchases in Norway, ICEV vehicles are much less expensive in Sweden. Furthermore, the tax system in Norway also makes BEVs cheaper to purchase than in their neighbouring country Sweden (Elbil.no, 2021). For instance, the Nissan Leaf has a starting price of €35787 in Sweden, but in Norway, the same vehicle costs €22507, a difference of €13280 in favour of Norway (Nissan.no, 2022, and Nissan.se, 2022).

In this paper, we add to the literature on the effectiveness of BEV incentives by examining road users' attitudes towards free public parking, the exemption from road tolls and access to transit lanes (bus transit, hereafter called transit) without passengers for BEV users. Our

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https://doi.org/10.1016/j.retrec.2023.101262
Received 5 September 2022; Received in revised form 2 February 2023; Accepted 8 February 2023
Available online 18 February 2023

Table 1
BEV buyer-related advantages. Source: IEAHEV, 2021.

Incentives	Intro year	BEV buyer-relative advantage	Future plans
Fiscal incentives: Reduction in purchase price/yearly cost gives competitive prices			
Exemption from registration tax	1990/ 1996	The tax is based on ICEV emissions and weight and is progressively increasing. Example ICEV taxes: VW Up €3000; VW Golf: €6000; larger vehicles even higher	To be continued unchanged at least until the end of 2021 and likely until the end of 2022.
VAT exemption	2001	Vehicles competing with BEVs are levied a VAT of 25% of the sales price	To be continued unchanged until at least the end of 2021 and likely until the end of 2022.
Reduced annual tax (formally a tax on vehicle insurance)	1996/ 2004	From 2021: BEVs and hydrogen vehicles €213, diesel/petrol: €297–307 (2021-figures).	TBD, last change was for 2021
Reduced company-car tax	2000	The company-car tax is 40% lower compared with ICEVs, but BEVs are seldom bought as company cars.	This incentive was up for revision in 2017/18 but remained in place.
Exemption from change in ownership tax	2018	Change in ownership tax: ICEVs 0–3-year-old vehicles +1200 kg: €660; 4–11-year-old: €398.	
Direct subsidies to users: Reduction in variable costs and help solving range challenges			
Reduced toll roads	1997	In Oslo, users save 60%, €360–600/year. In some places, savings exceed €1500.	Law revised so that rates for battery electric vehicles on toll roads and ferries are decided by local governments, up to a maximum rate of 50% of the ICEV rate. A national plan for toll infrastructure has been developed but is rather vague.
Reduced fares on ferries	2009	Similar to toll roads, saving money for those using car ferries.	
Financial support for normal charges	2009	Reduce investors' risk, reduce users' range anxiety, expand usage.	
Financial support for fast chargers	2011-	More fast-charging stations influences BEV kms driven & market shares.	ENOVA** has supported fast chargers along major corridors and in municipalities without chargers. City fast charging left to commercial actors.
Electricity tax: €0.0162/kWh. Much less than fuel taxes		Gasoline road use tax: €0.491/litre; Gasoline CO2-tax: €0.126/litre; Diesel: €0.362 +€0.145/litre respectively	Road use tax to be continued until it can be replaced by GPS road pricing.
User privileges: Reduction in time costs and providing users with relative advantages			
Access to transit lanes	2003/ 2005	Despite limitations, many BEV users save time driving to work in the transit lane during rush hours.	Local authorities have been given the authority to introduce restrictions if BEVs delay buses.
Free or reduced parking fees	1999	Users get a parking space, which is expensive, and save time.	Since 2017, local authorities can charge BEVs up to 50% of ICEV rates

*Implemented on 01.10.2017.

case study is located in the greater Oslo area, where BEV incentives have been in place since 1990. However, the purchase of BEVs had a sharp increase in the mid-2000s, probably because of new BEVs entering the market that could substitute for ICEVs such as the Nissan Leaf. Oslo has been ranked as the world capital of BEV usage since 2014. Furthermore, the Norwegian government is currently the front-runner in its ambition to use BEV incentives as a means of decarbonizing road transport. The data set used is from a questionnaire survey conducted annually in the 2014–2020 period. The research objective is to examine road user attitudes about BEV incentives in greater depth. To do so, a case study where BEV incentives are in place and are experienced by road users is chosen. Furthermore, the study uses longitudinal data to track changes in attitudes across years. Thus, the case study examines an ideal environment for tracking road users' attitudes towards BEV incentives while employing a rich data set. Such information provides useful insights, especially for policy makers in countries that are still in the innovator phase with limited incentives to offer. Furthermore, the study provides evidence for the Norwegian government of whether BEV incentives are necessary. In addition, it may be easier to make information campaigns about the adverse effects of the incentives for those who have the most positive attitude towards the incentives. Therefore, it may be easier to reduce the incentives with the worst adverse effects.

2. Literature review

Since the inception of government incentives to promote BEVs, several studies in the scientific literature have evaluated the effectiveness of such policies with observed and/or experimental data. Studies have shown that government incentives are likely effective in increasing the sales and usage of BEVs (i.e., Helveston et al., 2015; Wang et al., 2017; Jenn et al., 2018). However, Wang et al. (2018) did not find any significant positive effect of financial incentive policy on consumer intentions to adopt BEVs, contrary to their expectations (Wang et al., 2018). They reasoned that Chinese consumers are more concerned about convenience factors for BEV users, such as access to transit lanes, dedicated parking spaces and looser restrictions on the rules governing the use of vehicles by even- and odd-numbered licence plates, rather than financial incentives (Wang et al., 2018).

While the literature has investigated the effectiveness of government BEV incentives, there is yet another related issue that has not been adequately addressed. Few scholars have examined car users' attitudes towards BEV incentives, especially where such incentives are already in place. Such a study would indicate to policy makers which segments of the car user market to target with BEV incentives to achieve a wider acceptance of a gradual reduction in these economic benefits. Several studies have investigated the extent to which government BEV incentives are effective and how those incentives can contribute to BEV adoption. Such works are divided into (i) studies that used observed data, (ii) studies that used survey data/experimental data to infer how effective such incentives are and how they can contribute to the adoption of BEVs and (iii) studies that specifically looked at how effective Norwegian BEV incentives have been while using either (i) or (ii) above as a point of departure. Here, we provide a review of some studies in each of the categories named above.

Regarding the first category of studies, which used observed data to infer the effectiveness of BEV incentives, Jenn et al. (2018) used actual data from the US to investigate the impact of BEV incentives there. They found, among other things, that for every 1000 dollars offered in BEV purchase rebates, the sales of BEVs increased by 2.6%. Sierzchula et al. (2014) investigated the factors that influence the adoption of both BEVs and plug-in hybrid electrical vehicles (PHEVs) by using sales data from 30 countries. They found that financial incentives and charging infrastructure were significant factors explaining national market shares of electrical vehicles. Austmann (2021) conducted a comprehensive literature review of studies that examined drivers who adopted electrical vehicles (EVs) and focused on actual market data. Austmann (2021) found six different categories, namely, the *"Automobile sector, Incentives Socioeconomic/Sociodemographic, Infrastructure/Geography, Energy prices, Development EV and Psychological"*. The development EV category includes all variables that address the vehicle type itself. Psychology includes norms, attitudes, moral values and behaviour and seems to be underexplored (Austmann, 2021). The present study adds to the literature about attitudes, which Austmann (2021) found to be underexplored. Furthermore, Austmann (2021) found that socioeconomic factors such as age impacted the adoption of EVs.

Among the studies in the second category that used survey/experimental data to infer the effectiveness of BEV policies, Wang et al. (2017) conducted a discrete choice experiment in the context of China. They found that the policies that enhanced BEV acceptance and hence were most effective were exemptions from vehicle purchase and driving restrictions. Discounts and free access to BEV charging stations also positively impacted the acceptance of BEV policies. Another similar study was conducted by Helveston et al. (2015). Using data from choice-based conjoint surveys from 2012 to 2013 for China and the US, they assessed consumer preferences for ICEV, PHEV, and BEV technologies. Specifically, and relevant for our study, they found that despite similar incentives in the two countries, Chinese consumers were more willing to accept BEVs than their US counterparts. The reason was assumed to be that two-thirds of Chinese car buyers are first-time buyers. Thus, the ability to take long trips has not yet been established. Driving range expectations may therefore not be as problematic as in the US. Furthermore, China has a major intercity train system that is a very good alternative for longer trips, which is a less accessible alternative in the U.S. (Helveston et al., 2015). Their study implied the potential for BEV adoption in China, although that adoption would not necessarily mean a reduction in greenhouse emissions since coal is still the main part of electricity production in China (EIA, 2022). Several studies have found that policy instruments such as public charging points increase the adoption of BEVs (e.g., Egnér & Trosvik, 2018; Haustein et al., 2021). However, the driving range stress is likely to decrease as the driving range of BEVs increases. Many BEVs already have a range of over 500 km (Electric Vehicle, 2022). Haustein et al. (2021) found that information campaigns are important for the adoption of BEVs. Additionally, one result was the lack of knowledge among ICEV users about BEV attributes (i.e., the price, driving range, maintenance costs, and number of chargers at work, home and along highways). The present study could make it easier to create a more targeted information campaign.

The third category of studies examined the effectiveness of the Norwegian BEV policy in particular. There are many such studies because Norway is a world leader in this area. Figenbaum et al. (2015) investigated the experiences and opportunities for BEVs in Norway. They explored explanations for the developments in BEV usage in Norway by means of a narrative approach. They observed that increased BEV purchases and usage in Norway resulted from a long-lasting interaction between private enterprises, public authorities, and nongovernmental organizations combined with economic incentives that encouraged the purchase and use of BEVs. In addition, they remarked that the Norwegian government's support for the expansion of BEV battery charging stations would further enhance the purchase and usage of BEVs in the future. Their narrative has been supported by sales data, as the purchase and use of BEVs in Norway is constantly increasing. Zhang et al. (2016) examined the impact of car specifications, prices, and incentives for BEVs in Norway. They used BEV sales data for 2011–2013 and applied the random coefficient discrete choice model in their analyses. They found improvements in BEV technology, road space allotted and road toll waivers for BEV users. Additionally, the density of battery charging stations significantly impacted the demand for BEVs. Their findings therefore support those of, e.g., Figenbaum et al. (2015). Deuten et al. (2020) tested and analysed electric car incentive scenarios in the Netherlands and Norway. Their point of departure was to explore past and future BEV sales shares using a powertrain technology transition market agent model (PTTMAM). Their general findings indicated that emission regulation targets for manufacturers are necessary to prompt a transition from the sale of ICEVs to BEVs. Only strong incentives resulted in a significant sales share of BEVs in the Netherlands and Norway. Notably, their study did not concern BEV user subsidies but vehicle manufacturer regulations.

Perhaps the most closely related study surveyed motorists in New Zealand about their attitudes towards and perceptions of plug-in electric vehicles (BEVSs and PHEVs) (Broadbent et al., 2021). Furthermore, the popularity and awareness of incentives for both plug-in electric vehicles and ICEV users were investigated (Broadbent et al., 2021). They identified the factors that affect plug-in electric vehicle adoption. The results showed that the "strongest barriers [among New Zealand motorists] to plug in electric vehicles purchase were vehicle range, ICEV driver perceptions that plug in electric vehicles are expensive, inconvenience relating to charging and the unknown value proposition of batteries" (Broadbent et al., 2021).

The above literature review shows some examples of the three categories of i) studies that used observed data, (ii) studies that used survey data/experimental data to infer how effective such incentives are and how they can contribute to the adoption of BEVs and (iii) studies that specifically looked at how effective Norwegian BEV incentives have been while using either (i) or (ii) above as a point of departure. However, car users' attitudes towards BEV incentives, especially where incentives for BEV usage are already in place, as in Norway, have not been adequately studied in the literature. This observation corroborates the necessity of the present study as a contribution to the literature on road users' attitudes towards BEV incentives.

3. Norwegian BEV incentives

The incentive package in Norway is meant to induce car users to prefer BEVs over ICEVs as a means of decarbonizing road transport.

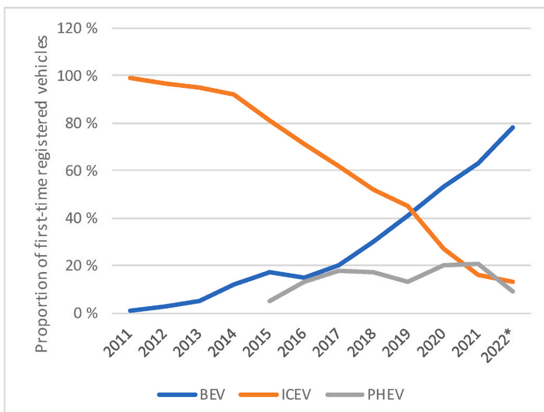

Fig. 1. The graph shows the proportion of first-time registered vehicles in Norway by fuel type over time. *Until March 2022. Source: NRPA, 2022.

Fig. 1 shows the proportion of first-time registered vehicles in Norway by fuel type over time. In March 2022, almost 80% of first-time registered vehicles were BEVs (NPRA, 2022). The proportion of first-time registered BEVs has increased sharply in recent years, while the share of ICEVs has decreased.

Many of the incentives in Norway date back to the 1990s. The BEV incentives are summarized in Table 1.

BEVs and other zero-emission cars have no purchase or registration taxes or value added tax (VAT), which a recent study found to be the most important factor to speed up the market uptake of BEVs in Norway (Østli et al., 2022).

In addition to lower annual and purchase taxes, BEV users have reduced variable costs and user privileges, such as reduced road tolls, reduced fares on ferries, free or reduced parking charges and access to transit lanes. In Oslo, the maximum parking charge for BEV users is 20% of what petrol and diesel cars pay (City of Oslo, 2021). BEV users have access to transit lanes. However, restrictions on the BEV use of transit lanes have been introduced by authorities where there is risk of congestion for public transport. Toll exemptions and discounts are an important reason why Norwegians are increasingly choosing BEVs (Figenbaum and Nordbakke, 2019; Bjerkan et al., 2016). The government mandates that BEV users pay a maximum of 50% of what petrol car users pay in tolls at existing toll stations (Ministry of Transport, 2017). Municipalities and county-level authorities determine the rates at individual toll stations; therefore, there are local variations.

The Oslo cordon toll system has several purposes. Tolls contribute to financing transport solutions, to zero growth in passenger car transport, to the transition to BEVs and to reducing congestion and greenhouse gas emissions (Bruvoll et al., 2020). However, some of these effects are contradictory. For example, BEV benefits can increase traffic and congestion (Bruvoll et al., 2020). At the same time, exemptions and reduced tariffs for BEVs reduce toll revenues and thus undermine their contribution to financing public transport, cycle paths and other measures to improve the urban environment (Bruvoll et al., 2020).

In summary, compared with the use of ICEVs, the use of BEVs is associated with lower taxes and more benefits. BEV owners can save €2000–3500 per year compared with ICEV owners due to much lower energy costs, local incentives and competitive sale prices resulting from tax exemptions (Figenbaum and Nordbakke, 2019).

4. Method and data

The data used in this study are based on an annual survey conducted since 1989. The Oslo cordon toll system was opened on 1 February 1990. Since 1989, an annual survey has been carried out among the populations of Oslo and Viken (formerly Akershus) about their attitudes towards various aspects of the toll stations. The main purpose of this series of reports and the annual survey is to uncover any behavioural and attitudinal changes over time (NPRA, 2020). However, in 2014, three questions were included asking to what extent citizens agreed or disagreed with the following BEV incentives: exemption from tolls, free public parking and access to transit lanes without passengers. These three questions are the dependent variables in this study. Hence, this study investigates road users' attitudes towards free parking, exemption from tolls and access to transit lanes without passengers from 2014 to 2020 (NPRA, 2020).

The annual survey includes a random and representative sample of approximately 1000 respondents living in Oslo and nearby municipalities (corresponding to old Akershus) who are aged 18 years or older (NPRA, 2020). Any biases in the net sample are statistically weighted according to publicly available statistics with regard to gender, age and geography (NPRA, 2020). Geographic weighting means that there is a proportional distribution of respondents from Oslo and Akershus. The sample comprised 49% women and 51% men. The mean age was 51 years, with a range of 18–99 years old. The surveys in 2014–2019 were carried out in February, May, August and November. The survey in 2020 was carried out in February, June, September and November. Annually, 250 interviews were conducted in each of the four rounds. The reason for this division into four waves is a desire to capture any seasonal variations in the results, in addition to obtaining results that to a greater extent reflect the average in attitudes throughout the year. By road user, we mean those who are above 18 years old. Ninety percent of the participants have a driver licence, but we also take into consideration passengers and those who cycle and walk. The data collection was conducted in the form of computer-assisted telephone interviews by professional data collection companies (Norfakta Markedsananlyse AS and Opinion). They are known to use well-grounded research methods to collect reliable data about any desired topic. They recruit most of their survey respondents from the previous research panels that they maintain. A total of 69% had studied at the university level, and approximately 14% had a BEV. Note that the share of BEVs is increasing, from 3% in 2014 to 25% in 2020. The participants received no compensation for taking part. The data were anonymized according to the European Union General Data Protection Regulation. The questionnaire included questions about whether the participants agreed to implement measures to reduce congestion and pollution. Such measures could include traffic congestion tolls and environmental tolls based on the vehicle type. Moreover, questions about whether they are satisfied with walking and cycling facilities and whether they use BEVs were included. Furthermore, socioeconomic data such as age, whether they have children, and the extent to which environmental concerns influence attitudes towards incentives were gathered. Important variables are described in Table 2a.

To select the variables in the model, we used a model building strategy called purposeful selection that can be summarized in 7 steps (Hosmer et al., 2013). One benefit of purposeful selection is that the analyst has full control of the method. "Purposeful selection has become a standard method of selection of variables in logistic regression" (Stavseth et al., 2020).

Respondents were asked the three following questions: "Do you agree or disagree that BEVs should have free public parking? Do you agree or disagree that BEVs should have access to transit lanes (without passengers)? Do you agree or disagree that BEVs should be exempted from tolls?" The possible responses were 1 = "disagree", 0 = "agree", or 2 = "do not know". Therefore, this is a discrete choice problem and not a case where the endogenous variable is continuous, for instance, in the case of ordinary least squares (OLS). The model has different categories but no natural order; accordingly, a multinomial approach is preferred. However, when we analysed the data, there were too few people in the category of those who "do not know" whether they agree or disagree with the exemption of BEVs in the Oslo cordon toll system. This affects our statistical analysis, as "a skewed distribution of the dependent variable can easily lead to problems, so it is better to have a 50/50 distribution than 5/95" (Melmehtoglu & Jakobsen, 2017). The correctness of the logit estimates depends on the sample size. In this case, less than 2% of respondents answered that they did not know for each of the dependent variables, while the two other categories that approve or disapprove of the BEV incentives share the last 98%. Especially if we do have fewer than 200 observations, this would create a problem of biased estimates (Melmehtoglu & Jakobsen, 2017), as is the case here for each dependent variable. Therefore, we omit this category from the calculations to obtain a more robust model. The dependent variable is thus binary; a person either agrees (=0) or disagrees with the incentives (=1). The variables included are based on the purposeful selection procedure for the dependent variable toll exemption as a standard binary logit model. The logit of Y is a linear function of the X variables. It can be formulated as follows (Hosmer et al., 2013, Mehmetoglu & Jakobsen, 2017):

$$L = \beta_0 + \beta_1 x_1 + \ldots\ldots + \beta_{k-1} x_{k-1} \tag{1}$$

where L is the total logit of Y, Y is the dichotomous variable, and k is the number of parameters in the model (the constant parameters and all the

Table 2a
Summary of important variables in the questionnaire.

Variable	Question asked	Code
Free public parking	Do you agree or disagree that BEVs should have free public parking?	1:disagree; 0:agree
Access to transit lanes without passengers	Do you agree or disagree that BEVs should have access to transit lanes (without passengers)	1:disagree; 0:agree
Exemption from toll	Do you agree or disagree that BEVs should be exempted from toll?	1:disagree; 0:agree
Age	How old are you?	Continious variable in year
Gender	what is your gender	1.female; 0; male* otherpossibilities was not an option.
Uni	Do you have education at university level?	1:yes; 0; otherwise
Highincome	Householdincome more than 1 mill NOK	1:yes; 0; otherwise
Household size	How many people live in the household in total, including all adults and children?	Continious variable in year
Children 0–6 years	Do you have chilrdren in the group 0–6 years old?	1:yes; 0; otherwise
Children 7–15 years	Do you have chilrdren in the group 7–15 years old?	1:yes; 0; otherwise
Children 16–19 years	Do you have chilrdren in the group 16–19 years old?	1:yes; 0; otherwise
Vehicles #	Does the household have a car, and if so, how many cars?	on a scale from 0 to 5
BEV	Do you have a BEV?	1: yes; 0; otherwise
Congestion	For better accessibility during rush hour and less pollution where the price is higher during rush hour and lower outside rush hour can be implemented*. Do you .	1:agree.2:disagree.3:do not know
Pollution	To reduce pollution, a tariff system where the price is higher for cars that pollute a lot, and lower for cars that pollute little, can be introduced*. Would you:	1:agree.2:disagree.3:do not know
Measures to reduce pollution	Do you think it is right or wrong to introduce measures that reduce pollution from car traffic during periods of poor air quality?	
Professional driver	Are you a professional driver, or do you drive a daily or weekly car to work on service assignments (for example to meetings, customers and the like	1:yes; 0: Otherwise
Area	Do you live in Oslo?	1:yes; 0: Otherwise
Finance Public transport	Part of the income from the toll ring in Oslo and between Oslo and Bærum today goes to the public transport system in Oslo and Akershus. The goal is faster development of the public transport service than with only ordinary allocations. The investment will, among other things, increase capacity, speed and multiple departures. Do you think it is right or wrong for road users who drive a car to pay for improvements to the public transport system in this way?	0:right; 1: wrong, 2; Do not know
Fuel	What type of fuel do your vehicle have?	1. Diesel,2. Gasoline 3. Hybrid,4. BEV 5. Do not have a car
Mode possibilities	Did you have the possibility to use antoher mode	1:Yes; 0: Otherwise
Satiesfied bike facilities	How satiesfied are you with the bike facilities in Oslo and Akershus?	0:Dissatisfied; 1: Satiesfied, 2: Do not know.
Satiesfied walking facilities	How satisfied are you with the facilities for walking in Oslo and Akershus?	0:Dissatisfied; 1: Satiesfied, 2: Do not know.
HowSaiesfiedPT	How satisfied are you with the standard of public transport in Oslo \ Akershus?	1:Very dissatiesfied; 2: Quite dissatisfied; 3:. Prettu satisfied,4. Very satiesfied, 5. do not know.
HowSatiesfiedMainroad	How satisfied are you with the standard of the main road network in Oslo and Akershus?	1:Very dissatiesfied; 2: Quite dissatisfied; 3:. Prettu satisfied,4. Very satiesfied, 5. Do not know.
Travel less with toll	How much do you agree or disagree with the statement: Tolls in the Oslo area means that you travel less by car	1: Disagree; 2:Agree; 3: Other/do not know
Attitudetoll_beforetoll	Do you think the introduction of tolls in the Oslo area was a very negative, quite negative, quite positive or very positive measure?	1:Very negative; 2: Quite negative; 3: Quite positive; 4: Very positive; 5: Do not know \ unanswered
Attitudetoll_afterInfo	The tolls are used together with public funds for measures in Oslo and Akershus within road construction and public transport Based on how the income has been used so far, what do you think about the introduction of tolls in the Oslo area?	1:Very negative; 2: Quite negative; 3: Quite positive; 4: Very positive; 5: Do not know \ unanswered
Mode	What type of transport mode did you use the last time you traveled to work	1: Public transport; 2: Private car as driver; 3: Private car as a passenger; 4:Other
Tollring_to_work	Do you usually have to pass toll booths in the Oslo area when you travel to and from work? (include all transport modes)	0:Yes; 1:No, 2; Do not know
Pay_toll	Does your job pay in full or in part the expenses you have for toll passes in the Oslo area?	1: Yes, completely; 2: Yes, in part; 3: No. 4:Not sure \ do not know
Inside/outside tollring	Do you live inside or outside the toll ring?	1:Inside; 2: Outside; 3: Unanswered \ do not know
Year	1:2014; 2:2015; 3:2016; 4:2017; 5:2018; 6:2019; 7:2019	1:2014; 2:2015; 3:2016; 4:2017; 5:2018; 6:2019; 7:2020

X variables).

However, we are investigating a case where we have three endogenous variables, namely, access to transit lanes, the exemption from tolls and free public parking. Therefore, after including the variables in the final model as just defined in equation (1), the model is expanded by using a model technique that can handle a large number of both endogenous and exogenous variables at the same time (Golob, 2003). The model technique is called structural equation modelling. However, the dependent variables are discrete; hence, a generalized structural equation modelling (GSEM) approach with a logistic distribution family is used. A GSEM with one dependent variable should be identical to the already mentioned logistic regression. However, when adding two more endogenous variables, the structural equation model estimates the three regression models simultaneously. It can be defined in the same way as the logit model as follows:

$$\left.\begin{aligned} L_1 &= \beta_{10} + \beta_{11}x_1 + \ldots\ldots + \beta_{1k-1}x_{k-1} \\ L_2 &= \beta_{20} + \beta_{21}x_1 + \ldots\ldots + \beta_{2k-1}x_{k-1} \\ L_3 &= \beta_{30} + \beta_{31}x_1 + \ldots\ldots + \beta_{3k-1}x_{k-1} \end{aligned}\right\} \quad (2)$$

where L is the total logit of the three different dichotomous variables, specifically, the exemption from tolls, free public parking, and access to transit lanes without passengers. All the equations have the different parameters estimated but take the same X variables. Only significant covariates were kept in the final model for the three equations. The estimation is performed with maximum likelihood in the same way as the logit models. Statistical software StataCorp (2021) was used to analyse the data.

5. Results and discussion

In this section, the results from the regression analysis are presented and discussed. The descriptive statistics for the variables included in the final model are described in Table 2b. The table shows, for instance, that approximately half of the participants disagree with the exemption from tolls, but 60–70% disagree with free public parking and access to transit lanes without passengers.

The model described in section 4 is used to investigate which factors affect attitudes towards toll exemptions, free public parking and access to transit lanes for BEV users. It is possible to compare the results of the GSEM with only one dependent variable with those of a binary logit model (Mehmetoglu & Jakobsen, 2017).

The results for the binary logistic regression model (only one dependent variable: toll exemption) indicate that we have 4684 units in our analysis. The chi-square value for the model is 973 with 38 degrees of freedom. This is highly significant ($p < 0.001$) and implies that the independent variables in the model have a significant effect on attitudes towards BEV incentives. The log likelihood chi test indicates that the model is a significant improvement compared with the one for the null hypothesis with only the intercept included. The McFadden R2 is 0.15.

Table 2b
Descriptive statistics for the variables included in the final model.

Variable	Obs	Mean	Std. dev.	Min	Max
Exemption from tolls	6363	0.51	0.50	0	1
Free public parking	6363	0.62	0.48	0	1
Access to transitlanes without passengers	6363	0.67	0.47	0	1
Age	6363	50.92	16.44	18	99
BEV	5640	0.14	0.34	0	1
Pollution	6363	1.67	0.75	1	3
Measures to reduce pollution	6363	1.23	0.50	1	3
Finance public transport	6363	1.38	0.57	1	3
Satiesfied with walking facilities	6363	0.88	0.43	0	2
Satiesfied with bike facilities	6363	0.80	0.80	0	2
Travels less with toll	6363	0.58	0.63	0	2
Children 0–6 years	5123	0.17	0.37	0	1
Chrildren 7–15 years	5123	0.23	0.42	0	1
Year	6363	2016.99	2.00	2014	2020

To test the quality of the model, a multicollinearity test is conducted. Multicollinearity indicates high correlations or high interrelations between the independent variables. The tolerance value (1/VIF) of each X-variable is the proportion of its variance that is not shared with the other X-variables. If the tolerance value is less than 0.2, then the estimated coefficient becomes less stable (Mehmetoglu & Jakobsen, 2017). In our model, the tolerance values are greater than 0.2 ($1/\text{VIF}>0.2$), and we thus conclude that there is no high level of multicollinearity between the independent variables.

The results of the model are shown in Table 3, which identifies the direction of the effect for the covariates, how significant the variables are, and the test statistics already mentioned. To interpret the results in a more intuitive way, the marginal effect is calculated to find the average predicted probabilities (Long & Freese, 2014). The results are presented in a different subsection depending on the impacts examined.

5.1. The effect of age and time

The dependent variables are whether the respondent agrees or disagrees with the exemption of BEVs from road tolls, free public parking, and access to transit lanes in the 2014–2020 period. This indicates their attitudes towards the incentives and whether they are positive or negative. The coefficients for age and year are significant and positive ($p < 0.001$, Table 4). The effect of age and time, with everything else held constant, is illustrated in Fig. 2 below.

Fig. 2 illustrates that the older respondents are, the more likely they are to have a negative attitude towards the BEV incentives studied. This is the case for all years, but attitudes are also more likely to become negative over time. For example, opinion in the youngest group is much less likely to be negative in 2014 than in 2020. All the years are compared to the base outcome in 2014. The coefficient for years is increasing (0.4–0.5 in 2015 to 1.3–1.9 in 2020). The average predicted probability calculated is shown in Table 4.

A person is almost 40 percentage points more likely to disagree with toll exemptions in 2020 than in 2014, with all other variables held constant (see Table 4).

A person is approximately 33 percentage points more likely in 2018–2020 to disagree with access to transit lanes without passengers for BEV users than in 2014, with all other variables held constant.

Similar trends are also found for free public parking. In 2020, a person is almost 30 percentage points more likely to disagree with free public parking than in 2014. The results therefore give a clear signal that the citizens of the Oslo region probably have a greater acceptance of reducing BEV incentives in 2020 than in 2014. Status quo bias is found to be an important factor in explaining attitudes towards congestion charging (Börjesson et al., 2016), as people prefer their current situation. Still, status quo bias may be only a partial explanation. During the time studied, the BEV incentives were reduced. However, disagreement started to decrease in 2015 and 2016. Hence, status quo bias is not the sole reason for this result. BEV users only started to pay a symbolic sum in the Oslo cordon toll system in 2019. In other places, they still are exempted from it. When congestion charging was introduced (2017), BEV users did not pay tolls. However, to a larger extent, people may have later agreed that it was reasonable that BEV users should pay, because the gap between ICEVs and BEVs became much larger. BEV users were exempted from parking in public places until 2017, at which point local communities could charge a maximum of 50% of the usual parking fee.

Those who have children from 0 to 6 years old are approximately 4–7 percentage points less likely to disagree with the three incentives investigated here ($p < 0.1$) than those who do not have children in that age range, with everything else held constant. Those with children from 7 to 15 years old are 4–5 percentage points less likely to disagree with the exemption from tolls and free public parking than those without

Table 3
Results from the generalized structural equation model.

Endogenous variables		Coef.	Std. Err.	z	P > z	[95% Conf.	Interval]	Coef.	Std. Err.	z	P > z	[95% Conf.	Interval]	Coef.	Std. Err.	z	P > z	[95% Conf.	Interval]
			Exemption from tolls							*TransitWITHOUTpassenger*							*Free public parking*		
Age		0.028	0.002	11.73	0.000	0.023	0.033	0.021	0.002	8.9	0.000	0.016	0.025	0.024	0.002	10.16	0.000	0.020	0.029
Finance public transport																			
	Wrong	0.274	0.078	3.51	0.000	0.121	0.426												
	Do not know	0.230	0.165	1.39	0.164	−0.094	0.553												
BEV		−1.731	0.106	−16.39	0.000	−1.938	−1.524	−1.312	0.093	−14.07	0.000	−1.495	−1.129	−1.524	0.096	−15.85	0.000	−1.713	−1.336
Pollution																			
	Against	0.326	0.100	3.25	0.001	0.129	0.523	0.257	0.077	3.36	0.001	0.107	0.407	0.561	0.078	7.15	0.000	0.407	0.715
	Do not know	0.299	0.129	2.32	0.021	0.046	0.552	0.159	0.096	1.65	0.099	−0.030	0.347	0.408	0.096	4.25	0.000	0.220	0.597
Agreereducepollution																			
	Wrong	0.318	0.094	3.37	0.001	0.133	0.503							0.248	0.096	2.58	0.010	0.060	0.437
	Do not know	0.375	0.182	2.07	0.039	0.019	0.731							0.181	0.186	0.97	0.332	−0.184	0.545
Satiesfied walking facilities																			
	Satiesfied	−0.231	0.094	−2.46	0.014	−0.416	−0.047												
	Do not know	−0.137	0.187	−0.73	0.465	−0.503	0.230												
Satiesfied bike facilites																			
	Satiesfied	0.490	0.212	2.31	0.021	0.075	0.905							0.680	0.205	3.33	0.001	0.279	1.081
	Do not know	0.475	0.213	2.22	0.026	0.056	0.893							0.668	0.213	3.13	0.002	0.250	1.086
Travellesswithtoll																			
	Agree	−0.308	0.096	−3.19	0.001	−0.497	−0.119	−0.168	0.070	−2.39	0.017	−0.305	−0.030	−0.113	0.070	−1.61	0.107	−0.251	0.025
	Do not know	0.039	0.234	0.16	0.869	−0.420	0.497	−0.076	0.160	−0.48	0.634	−0.389	0.237	−0.039	0.160	−0.25	0.806	−0.354	0.275
Children 0-6years		−0.185	0.094	−1.98	0.048	−0.369	−0.002	−0.274	0.090	−3.06	0.002	−0.450	−0.098	−0.314	0.090	−3.47	0.001	−0.492	−0.137
Children 7–15years		−0.144	0.078	−1.85	0.065	−0.297	0.009							−0.226	0.077	−2.95	0.003	−0.376	−0.076
Year																			
2015		0.541	0.160	3.37	0.001	0.226	0.855	0.506	0.115	4.41	0.000	0.281	0.731	0.413	0.154	2.69	0.007	0.112	0.714
2016		0.663	0.169	3.93	0.000	0.333	0.994	0.411	0.113	3.62	0.000	0.189	0.634	0.436	0.162	2.69	0.007	0.119	0.754
2017		0.847	0.176	4.81	0.000	0.502	1.192	1.054	0.120	8.76	0.000	0.818	1.290	1.083	0.173	6.24	0.000	0.743	1.423
2018		1.220	0.186	6.57	0.000	0.856	1.583	1.462	0.130	11.29	0.000	1.208	1.716	1.205	0.183	6.6	0.000	0.847	1.563

(*continued on next page*)

Table 3 (*continued*)

		Coef.	Std. Err.	z	P > z	[95% Conf.	Interval]	Coef.	Std. Err.	z	P > z	[95% Conf.	Interval]	Coef.	Std. Err.	z	P > z	[95% Conf.	Interval]
Endogenous variables			*Exemption from tolls*							*TransitWITHOUTpassenger*							*Free public parking*		
2019		1.328	0.190	6.99	0.000	0.955	1.700	1.555	0.129	12.02	0.000	1.302	1.809	1.516	0.191	7.93	0.000	1.142	1.891
2020		1.887	0.204	9.26	0.000	1.488	2.287	1.593	0.132	12.04	0.000	1.334	1.852	1.647	0.204	8.09	0.000	1.248	2.046
Pollution#Lesstravelwithtoll																			
	Against#1	0.476	0.154	3.08	0.002	0.173	0.779												
	Against#2	−0.015	0.368	−0.04	0.968	−0.736	0.706												
	Do not knowt#1	0.062	0.193	0.32	0.746	−0.316	0.441												
	Do not know#2	0.258	0.401	0.64	0.519	−0.527	1.043												
Satiesfiedbikefacilities#Year																			
	1#2015	−0.099	0.296	−0.33	0.739	−0.678	0.481							−0.491	0.289	−1.7	0.089	−1.056	0.075
	1#2016	−0.159	0.286	−0.56	0.578	−0.720	0.401							−0.377	0.281	−1.34	0.180	−0.927	0.174
	1#2017	−0.158	0.289	−0.55	0.583	−0.724	0.407							−0.555	0.289	−1.92	0.055	−1.121	0.012
	1#2018	−0.522	0.297	−1.76	0.079	−1.105	0.060							−0.866	0.293	−2.95	0.003	−1.440	−0.291
	1#2019	0.066	0.292	0.23	0.820	−0.505	0.638							−0.552	0.292	−1.89	0.058	−1.124	0.019
	1#2020	−0.297	0.302	−0.98	0.325	−0.889	0.295							−0.437	0.302	−1.45	0.148	−1.030	0.155
	2#2015	−0.297	0.305	−0.97	0.331	−0.894	0.301							−0.564	0.306	−1.85	0.065	−1.163	0.035
	2#2016	−0.184	0.298	−0.62	0.536	−0.768	0.400							0.065	0.307	0.21	0.831	−0.535	0.666
	2#2017	−0.685	0.300	−2.29	0.022	−1.272	−0.098							−0.977	0.304	−3.22	0.001	−1.572	−0.382
	2#2018	−0.149	0.309	−0.48	0.631	−0.754	0.457							0.024	0.328	0.07	0.941	−0.618	0.666
	2#2019	−0.236	0.322	−0.73	0.464	−0.867	0.395							−0.714	0.328	−2.18	0.029	−1.356	−0.072
	2#2020	−0.647	0.324	−2	0.046	−1.281	−0.012							−0.555	0.334	−1.66	0.097	−1.210	0.100
_cons		−2.172	0.205	−10.62	0.000	−2.573	−1.771	−0.962	0.150	−6.4	0.000	−1.257	−0.668	−1.586	0.177	−8.95	0.000	−1.934	−1.239
Number of obs		4684																	
Log likelihood		−8121																	

Table 4
Marginal results from the generalized structural equation model.

Variables		dy/dx	Std.Err.	z	P > z	[95% Conf.	Interval]
Age							
	Exemption from tolls	0.007	0.00	11.69	0.000	0.006	0.008
	Free public parking	0.006	0.00	10.22	0.000	0.004	0.007
	TransitWITHOUTpassenger	0.004	0.00	8.94	0.000	0.003	0.005
0. No children 0–6years		(base	outcome)				
1. Children 0–6 years							
	Exemption from tolls	−0.046	0.02	−1.97	0.048	−0.092	0.000
	Free public parking	−0.074	0.02	−3.40	0.001	−0.117	−0.031
	TransitWITHOUTpassenger	−0.060	0.02	−2.97	0.003	−0.100	−0.020
0. No children 7–15 years		(base	outcome)				
1. Children 7–15 years							
	Exemption from tolls	−0.036	0.02	−1.86	0.063	−0.074	0.002
	Free public parking	−0.053	0.02	−2.91	0.004	−0.088	−0.017
	TransitWITHOUTpassenger						
2014.year		(baseoutcome)					
2015.year							
	Exemption from tolls	0.102	0.03	3.55	0.000	0.046	0.158
	Free public parking	0.029	0.03	0.96	0.335	−0.030	0.089
	TransitWITHOUTpassenger	0.125	0.03	4.45	0.000	0.070	0.180
2016.year							
	Exemption from tolls	0.134	0.03	4.77	0.000	0.079	0.189
	Free public parking	0.082	0.03	2.76	0.006	0.024	0.140
	TransitWITHOUTpassenger	0.102	0.03	3.65	0.000	0.047	0.157
2017.year							
	Exemption from tolls	0.150	0.03	5.26	0.000	0.094	0.205
	Free public parking	0.162	0.03	5.53	0.000	0.105	0.219
	TransitWITHOUTpassenger	0.248	0.03	9.16	0.000	0.195	0.301
2018.year							
	Exemption from tolls	0.245	0.03	8.29	0.000	0.187	0.303
	Free public parking	0.220	0.03	7.45	0.000	0.162	0.277
	TransitWITHOUTpassenger	0.323	0.03	12.31	0.000	0.271	0.374
2019.year							
	Exemption from tolls	0.312	0.03	10.68	0.000	0.254	0.369
	Free public parking	0.266	0.03	9.34	0.000	0.210	0.322
	TransitWITHOUTpassenger	0.338	0.03	13.13	0.000	0.287	0.388
2020.year							
	Exemption from tolls	0.387	0.03	13.57	0.000	0.331	0.442
	Free public parking	0.302	0.03	10.77	0.000	0.247	0.358
	TransitWITHOUTpassenger	0.343	0.03	13.27	0.000	0.293	0.394
0: ICEV		(baseoutcome)					
1.BEV	Exemption from tolls	−0.384	0.02	−21.22	0.000	−0.419	−0.348
	Free public parking	−0.363	0.02	−17.15	0.000	−0.405	−0.322
	TransitWITHOUTpassenger	−0.308	0.02	−14.01	0.000	−0.351	−0.265

children in that age group, with all other variables controlled for ($p < 0.1$). People with small children may be more likely to drive during rush hours to pick up their children (especially those under 6 years old, who are not allowed to go home alone). Therefore, they may have a greater benefit from BEV incentives than those who may have higher flexibility in their work hours. A recent study also found that couples with children are largely overrepresented among BEV owners (Fevang et al., 2021). The same study also found that BEV owners tend to be in the 25–44 age group. Hence, it is natural that young people and those with children would be less negative towards BEV incentives, since they are likely to obtain the benefits of the incentives.

5.2. *The impact of fuel type on attitudes towards BEV incentives*

The next variable considers whether BEV users have a different attitude than ICEV users; see the marginal results in Table 4. The variable "BEV" is also significant ($p < 0.001$) and suggests that a BEV user is 31–38 percentage points less likely to disapprove of the economic benefits of BEVs than ICEV users. This is logical since they receive these economic benefits, which is one reason why people buy BEVs (Bjerkan et al., 2016; Figenbaum and Nordbakke, 2019). However, Fig. 3 shows that although BEV owners are still less likely to have a negative opinion, the share of those who disagree with the economic benefits is increasing. Fig. 3 shows the probability of disagreement of the three incentives. The red line identifies those who have a BEV, and the blue line identifies those who do not. Recall that the share of BEVs is increasing, from 3% in 2014 to 25% in 2020. There is a jump in the likelihood of ICEV users disagreeing with BEV incentives in 2017. The reason is likely the introduction of congestion tolls, which were implemented in the study area in 2017. Congestion tolls indicate a higher toll during rush hour, which increases costs for ICEV users, while BEV users were still exempted from the toll. During rush hour, the toll increased by approximately 50% for petrol vehicles and almost 60% for diesel vehicles (Fjellinjen, 2022).

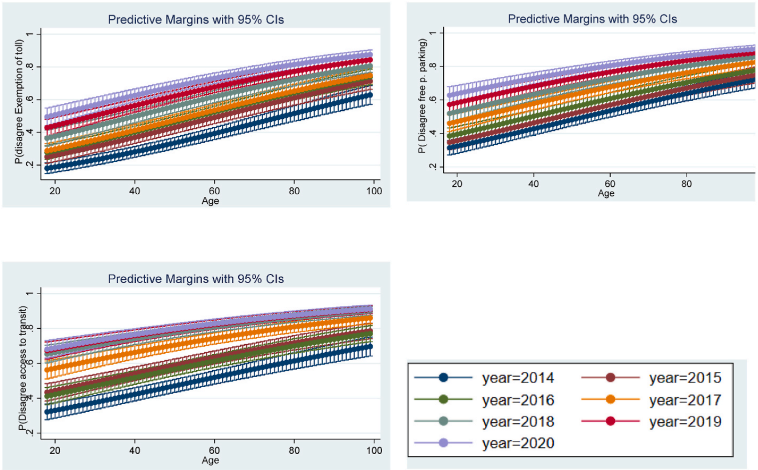

Fig. 2. Probability of disapproving of the incentives studied in 2014–2020.

5.3. *Impact of environmental concerns*

This section represents environmental concerns divided into the three variables of “finance public transport”, “pollution” and “measures to reduce pollution”. See the marginal results in Table 5.

The participants in the questionnaire were informed of the following: “Part of the income from the toll ring in Oslo and between Oslo and Bærum today goes to the public transport system in Oslo and Akershus. The goal is faster development of the public transport service than with only ordinary allocations. The investment will, among other things, increase capacity, speed and multiple departures”. Thereafter, they were asked “Do you agree or disagree that road users who drive a car should pay for improvements to the public transport system in this way?” The variable “finance public transport” represents this question as a dummy variable, where the possible answers are “agree”, “disagree” or “do not know”. “Agree” is the reference category. This variable is excluded from the regression for access to transit lanes and free public parking because it is nonsignificant. Compared to those who agreed that tolls should be used on public transport, those who disagreed were 7 percentage points ($p < 0.05$) more likely to be negative towards toll exemptions for BEV users.

The variable “pollution” represents whether the participants agree or disagree with a toll system based on vehicle-generated pollution. This is a dummy variable, where “agree” is the reference category. Those who disagree with such a system are also 13 percentage points more likely to disapprove of toll exemptions and free public parking and 5 percentage points more likely to disagree with access to transit lanes without passengers than those who agree with such a system.

The variable “measures to reduce pollution” represents those who agree as a reference category that measures to reduce pollution, i.e., environmental speed limits, should be implemented. Environmental speed limits are used to reduce local pollution by, for instance, reducing the traffic speed limit from 80 km/h to 60 km/h in the winter (Lopez-Aparicio et al., 2020). Those who disagree or do not know are 5–8 percentage points ($p < 0.05$) more likely to disapprove of free public parking and the exemption from tolls for BEVs than those who approve of the implementation of measures that reduce pollution when all other variables are controlled for.

The results from the three variables described above indicate that those who disagree that environmental travel policies, such as the use toll on public transport and toll charges based on vehicle-generated pollution, should be implemented are more likely to disapprove of BEV benefits. The implied intent of the BEV incentives is to make people change vehicles from ICEVs to BEVs. Thus, the results indicate that those with greater environmental concerns are more likely to be positive towards BEV incentives. Environmental concerns are found to be important for early adopters of BEVs (Bjørge et al., 2022). However, the characteristics of BEV owners in Norway are becoming more similar to those of other car owners (Fevang et al., 2021).

5.4. *Impact of satisfaction with soft modes and whether tolls impact travel habits*

This section represents those who are satisfied with soft modes encouraging active mobility, such as walking or cycling, and whether tolls impact their travel habits. See the marginal results in Table 5. Those who are satisfied with walking facilities in the greater Oslo area show a significant opinion only for the dependent variable “road toll exemption”. The variable was originally a 5-point scale from very dissatisfied to very satisfied. The fifth alternative was “do not know” (see Table 2a). To simplify the alternatives and presentations in this study, we combine very dissatisfied and quite dissatisfied responses and quite satisfied and very satisfied responses. As a result, we obtain three different groups, namely, dissatisfied as the reference category, satisfied and do not know. Those who are satisfied with the walking facilities are 6 percentage points less likely to disapprove of toll exemptions compared to those who are dissatisfied with the walking facilities. The category “do not know” does not significantly differ from the reference category in the respondents’ disagreement of toll exemptions.

Similar to the variable “walking facilities”, the variable satisfied with bike facilities is reduced to a three-point scale. Compared with those who are dissatisfied with the cycle path network in the larger Oslo area, those who are satisfied are 8 percentage points more likely ($p < 0.05$) to disagree with toll exemptions and 5 percentage points more likely ($p < 0.05$) to disagree with free public parking, while those who do not know are 5 and 7 percentage points more likely ($p < 0.05$) to disagree with toll exemptions and free public parking, respectively, with everything else held constant. This result is logical, as walking is rarely a substitute for a vehicle, but a bicycle can be a substitute for a vehicle for a variety of distances. However, there is also a significant interaction term between how satisfied people are with bike facilities and the year (see Table 3, $p < 0{,}1$). For the dependent variable exemption from tolls, the interaction term is significant only in 2018 for those who are satisfied with bike facilities and in 2017 for those who do not have any opinion about the

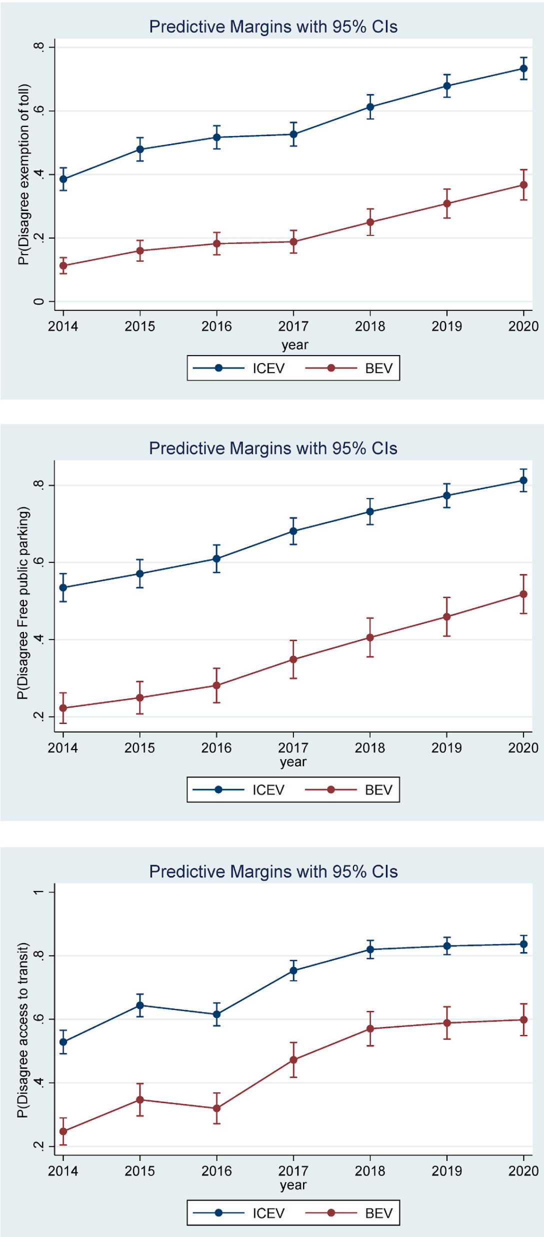

Fig. 3. Probability of disagreement with toll exemptions, free public parking and access to transit lanes without passengers for BEV users and ICEV users.

bike facilities. Compared to the benchmark outcome (dissatisfied with bike facilities in 2014), the results of other groups are less likely to be negative towards the exemption from tolls. Furthermore, from 2017 to 2019, those who were satisfied with bike facilities were less likely to be negative towards free public parking than those who were dissatisfied in the benchmark year of 2014. Those who do not know what they think about bike facilities are also less likely to be negative towards free public parking in 2017, 2019 and 2020 compared to those who are not satisfied with the bike facilities in the benchmark year 2014. The reason may be that in 2018, the congestion toll system had already been implemented for a year, and local communities could take parking charges for BEVs; therefore, people may have changed their travel habits after a year.

Those who report that they travel less with the Oslo cordon toll system are 3–4 percentage points ($p < 0.1$) less likely to disagree with BEV incentives than those who report that they do not travel less with the Oslo cordon toll system. This result is logical because those who change travel patterns because of a toll are more strongly affected by the toll. BEV users are less affected by tolls since they pay less; thus, those who have changed their travel patterns may support BEV incentives to a greater extent. The variable is also significant as an interaction term with the variable “pollution”. The results are shown in Fig. 4. Fig. 4 illustrates that those who disagree with the toll system based on vehicle-generated pollution are also more likely to have a negative attitude towards the exemption from tolls, as already discussed in section 5c. Furthermore, this illustrates that those who state that they travel less because of tolls are also more likely to disagree with the toll system based on vehicle-generated pollution.

This study examines road users’ attitudes towards BEV incentives by employing a rich data set. It provides evidence of decreasing support for incentive policies; for instance, the opinions of citizens in the larger Oslo area towards toll exemptions are approximately 40 percentage points more likely to be negative in 2020 than 2014, with all the other variables controlled for. We see the same tendency with the other two incentives. This is important for the Norwegian government to know when considering reducing incentives. The study confirms that information campaigns are important and indicates that, for instance, younger people are more likely to be in favour of such benefits.

6. Concluding remarks and policy implications

Many studies have investigated the extent to which government BEV incentives are effective and how those incentives can contribute to BEV adoption. However, few if any studies have examined car users’ attitudes towards BEV incentives and mapped the development of these attitudes over time.

The present study is a case study of the greater Oslo area; Oslo has been ranked as the world capital of BEV usage since 2014. Furthermore, the Norwegian government is currently a front-runner in terms of its comprehensive use of BEV incentives as a means of decarbonizing road transport. The data set used is from an annual questionnaire survey conducted each year for the period of 2014–2020. Respondents were asked to express their attitudes towards the different BEV incentives in place.

The study was intended to help decision makers identify the factors that affect attitudes towards the three economic benefits for BEV users of free public parking, access to transit lanes without passengers, and exemption from tolls in the greater Oslo area. There is already an ongoing discussion in Norway about reducing these incentives. This study shows the changes over the years 2014–2020 in Oslo citizens’ attitudes towards individual economic benefits. If the government gives clear signals of why and how these economic benefits change, it may be easier for the people to accept the reduction in incentives offered. The battery price is falling (Bloomberg, 2021); hence, the relative price difference between BEVs and ICEVs is decreasing. The information derived from this study could then be used to inform those groups of road users who are the most positive towards the incentives about adverse effects of the incentives. Furthermore, such information would be valuable for other countries considering incentives to promote the purchase and use of BEVs. Similar studies also found that BEV users highlighted the driving characteristics, silence and exciting technology as incentivizing (Ingeborgrud & Ryghaug, 2019). Several of the incentives were perceived as a bonus and not perceived as necessary to engender the purchase of a BEV, except for those with the least comfortable vehicle (Buddy), which also indicates that BEV users should

Table 5
Marginal results from the generalized structural equation model.

Variables		dy/dx	Std.Err.	z	P > z	[95% Conf.	Interval]
1.Agree finance public transport		(baseoutcome)					
2.Disagree finance public transport							
	Exemption from tolls	0.068	0.02	3.53	0.000	0.030	0.106
	Free public parking	–	–	–	–	–	–
	TransitWITHOUTpassenger	–	–	–	–	–	–
3. Do not know_ finance public transport							
	Exemption from tolls	0.057	0.04	1.40	0.161	−0.023	0.137
	Free public parking	–	–	–	–	–	–
	TransitWITHOUTpassenger	–	–	–	–	–	–
1.Pollution		(baseoutcome)					
2.Pollution							
	Exemption from tolls	0.131	0.02	6.87	0.000	0.093	0.168
	Free public parking	0.127	0.02	7.36	0.000	0.093	0.161
	TransitWITHOUTpassenger	0.054	0.02	3.40	0.001	0.023	0.086
3.Pollution							
	Exemption from tolls	0.084	0.02	3.62	0.000	0.039	0.130
	Free public parking	0.095	0.02	4.39	0.000	0.052	0.137
	TransitWITHOUTpassenger	0.034	0.02	1.68	0.094	−0.006	0.074
1.Measures to reducepollution		(baseoutcome)					
2.Disagree with measures to reduce pollution							
	Exemption from tolls	0.079	0.02	3.40	0.001	0.033	0.125
	Free public parking	0.056	0.02	2.66	0.008	0.015	0.096
	TransitWITHOUTpassenger	–	–	–	–	–	–
3. Do not know							
	Exemption from tolls	0.093	0.04	2.11	0.035	0.007	0.179
	Free public parking	0.041	0.04	1.00	0.319	−0.039	0.121
	TransitWITHOUTpassenger	–	–	–	–	–	–
1.Dissaiesfied walking facilities		(baseoutcome)					
2.Satiesfied walking facilities							
	Exemption from tolls	−0.058	0.02	−2.48	0.013	−0.103	−0.012
	Free public parking						
	TransitWITHOUTpassenger						
3.Do not know							
	Exemption from tolls	−0.034	0.05	−0.73	0.466	−0.125	0.057
	Free public parking						
	TransitWITHOUTpassenger						
1.Dissatiesfied bike facilities		(baseoutcome)					
2.Satiesfied bike facilities							
	Exemption from tolls	0.081	0.02	4.18	0.000	0.043	0.119
	Free public parking	0.050	0.02	2.76	0.006	0.014	0.085
	TransitWITHOUTpassenger	–	–	–	–	–	–
3. Do not know							
	Exemption from tolls	0.040	0.02	1.86	0.063	−0.002	0.083
	Free public parking	0.064	0.02	3.17	0.002	0.024	0.103
	TransitWITHOUTpassenger	–	–	–	–	–	–
1.Travel less with toll		(baseoutcome)					
2.Travel less with toll (Agree)							
	Exemption from tolls	−0.034	0.02	−1.96	0.050	−0.069	0.000
	Free public parking	−0.026	0.02	−1.61	0.108	−0.058	0.006
	TransitWITHOUTpassenger	−0.036	0.01	−2.38	0.017	−0.065	−0.006
3.Travel less with toll (do not know)							
	Exemption from tolls	0.019	0.04	0.48	0.633	−0.059	0.097
	Free public parking	−0.009	0.04	−0.24	0.807	−0.081	0.063
	TransitWITHOUTpassenger	−0.016	0.03	−0.47	0.638	−0.082	0.050

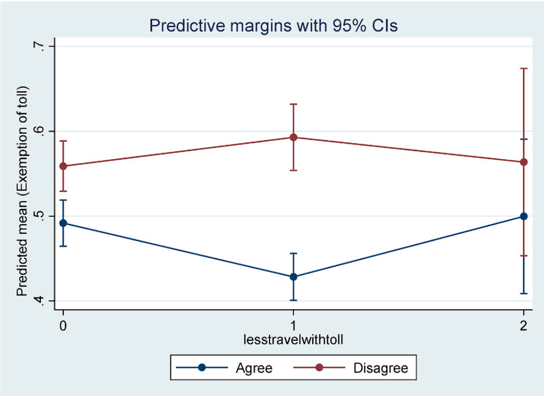

Fig. 4. Probability of disagreement with toll exemptions measured for the variables less travel with tolls and the variable "pollution".

not be treated as a homogenous group (Ingeborgrud & Ryghaug, 2019). People living in greater Oslo are starting to disagree with beneficial BEV incentives such as those already mentioned. BEV users are significantly less likely to disagree with the incentives than ICEV users; however, the share who disagree is increasing. As individuals grow older, they become more likely to disagree with the incentives and perhaps are likely to be less tolerant that the government funds such incentives. Children also tend to matter; those with children under 15 years old are less likely to disagree with the incentives. This corresponds with other studies. Socioeconomic characteristics such as age and having children in the household also impact the adoption of BEVs (Austmann, 2021; Fevang et al., 2021). Naturally, those who obtain the benefits of incentives will be less negative towards them. Those who are satisfied with the cycle path network also have a higher probability of disagreeing with the incentives. Environmental concerns are found to be important for early adopters of BEVs (Bjørge et al., 2022). The results indicate that those with greater environmental concerns are more likely to be positive towards BEV incentives. However, the characteristics of BEV owners in Norway are becoming more similar to those of other car owners (Fevang et al., 2021). Policies from the Norwegian government have consistently obtained their intended results, i.e., an increase in BEV market share over growth in ICEVs. It may be time to wind back such policies. The market is mature, and spending on such policies is becoming less acceptable to the public; the purchase price relative to ICEVs is also coming down (Bloomberg, 2021), and these incentives will no longer be needed in the near future in Norway.

7. Limitations and further research

One of the limitations of this study is that people traveled less in 2020 due to the coronavirus pandemic; hence, their attitudes in that particular year may have been influenced. Furthermore, it would be interesting to investigate whether the pandemic has changed attitudes. For instance, Oslo citizens recommended not taking public transport during lockdown, which may have increased the demand for BEVs. Another limitation of the study is that the results cannot be assumed to be generalizable due to the different socioeconomic compositions of cities/countries. In addition, Norway is quite unique in regard to its BEV purchase and user incentives. These factors have led to the world's largest share of BEVs per capita in recent years. It is therefore difficult to compare Norway with other countries. The dependent variables could have had a larger Likert scale to differentiate them more. However, the results may be seen as evidence that such strong incentives are not necessary even for users as the market matures. Nonetheless, the incentives have, as already mentioned, led to a sharp increase in purchases and use. Therefore, they may have been necessary in the short run, but it may be time to reduce them in Norway.

CRediT authorship contribution statement

Marie Aarestrup Aasness: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing - original draft, Writing – review & editing. **James Odeck:** Writing – review & editing, Supervision.

Acknowledgements

We are indebted to Professor Svein Bråthen at Molde University College for his many valuable comments when drafting this paper. We would also like to thank two anonymous reviewers for their valuable comments and suggestions for this paper. We are grateful to the Norwegian Public Roads Administration (NPRA) for supplying the data that have made this useful study possible. Any errors are, however, our sole responsibility and should not be attributed to any of the individuals or institutions named above.

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ISBN 978-82-326-5512-0 (printed ver.)
ISBN 978-82-326-6618-8 (electronic ver.)
ISSN 1503-8181 (printed ver.)
ISSN 2703-8084 (online ver.)

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