Congestion Charges: The Relationship between Charging Complexity, Public Acceptability and Effectiveness

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ABSTRACT

An important aspect of congestion charging is its complexity which varies according to charging dimensions such as time, location, type of vehicle etc. and the sub levels of those dimensions. Charging complexity is expected to influence the effectiveness of the congestion charge and the public acceptability level. However, the direction and magnitude of these influences are unknown. Therefore, the main research question in this thesis research is: *What is the relationship between congestion charging complexity levels and utility in terms of the effectiveness of the congestion charge and the public acceptability level, from the perspective of policy makers?*

Consider a utility for policy makers, that is based on effectiveness (E) and public acceptability (A); if both effectiveness and acceptability are influenced by charging complexity levels (CL), how would utility be affected by charging complexity levels? This thesis research aims to convert this utility function to a function of complexity levels and give an answer to this question. This is illustrated below.

$$U = \beta_{Effectiverness} * E + \beta_{Acceptability} * A \qquad \rightarrow \qquad U = C + mCL$$

[U = Utility, E = Effectiveness, A = Public acceptability, C = Constant, m = Coefficient, CL = Complexity level, $\beta_{Effectiverness}$ = Effectiveness parameter, $\beta_{Acceptability}$ = Acceptability parameter.]

In most basic terms, utility is defined as the measure of usefulness of a certain thing for someone. In this this thesis research, utility is the measure of usefulness of congestion charging plans for policy makers. A higher utility is perceived to yield a better outcome in terms of the attributes it is based on. Effectiveness is defined as the reduction in traffic volume during charging hours.

The relationship between complexity and effectiveness was investigated through a desk research; the relationship between complexity and acceptability was investigated through a rating experiment. Regression analysis was used to express effectiveness and acceptability as functions of complexity levels. A stated choice experiment was performed and the parameters of the utility function – as an MNL (logit) model – were estimated from the perspective of policy makers. Then, the utility function was converted to a function of complexity. Further sensitivity analysis was performed by performing the analysis in a smaller scale within different demographics in the existing data of the rating and choice experiments.

There were two key limitations to this research. **(1)** One of the primary limitations in this thesis research was the difficulty of investigating the relationship between effectiveness and complexity. Previous studies that looked into this relationship had used models based on survey data. However, given funding and long research periods, those studies [(Department for Transport, 2004), (Bonsall, Shires, Ngoduy, et al., 2007), (Link, 2015)] could not conclude a strong relationship between complexity and effectiveness. In addition, using survey data does not accurately represent real-life choices that people make. Thus, instead of doing a similar survey as previous studies did, I chose to investigate if there was a relationship between complexity and effectiveness in real-life congestion charge implementations. If there was a visible trend among real-life congestion charge implementations, it could hint that there was a significant relationship between complexity and effectiveness. There was a fundamental limitation when analyzing real-life congestion charging implementations and that was the scarcity of data. Successful implementations for

which the data was available were limited to only five cases (Börjesson & Kristoffersson, 2015). Observing five cases would nowhere near be enough to do an inductive statistical analysis, let alone provide proof for a significant relationship. Nonetheless I investigated those cases in detail and performed a regression analysis; and unfortunately, there was no indication of a positive or negative trend. Observing different cases provided different results. **(2)** Another key limitation is that there are a lot of factors that influence effectiveness other than complexity; and in my analysis, I tried to limit the effects of those other factors. I took into account the initial congestion levels – which Börjesson et al. (2014) states as the most important factor influencing effectiveness – and the cost of the charges. However, the inconsistency of results based on observing different cases shows that there are other factors that influence effectiveness which I did not account for. A very important unaccounted factor might be the policy objective. Bonsall et al. (2007) state that people's behavioral changes can depend on the policy objective and how it was revealed to them. The examples of Stockholm and Gothenburg support this theory. Stockholm and Gothenburg adopted very similar congestion charges with the same level of complexity, but their policy objectives were different. Stockholm aimed at reducing congestion whereas Gothenburg aimed at reducing congestion but also equally important at gathering revenue for public investments. Stockholm had significantly higher reduction in congestion (22%) compared to Gothenburg (12%) within the first year after implementation. The unaccounted factor of policy objective made the analysis of real-life congestion charging implementations more difficult than it already was.

Due to these key limitations, the relationship between complexity and effectiveness does not have a conclusive direction. Therefore, for the utility, I covered both cases when the relationship between complexity and effectiveness was both positive and negative. I used the effectiveness functions that resulted from the analysis of real-life congestion charging implementations.

The results show that, as the answer to the main research question, **it can be concluded that utility increases as the complexity level increases, from the perspective of policy makers.** Sensitivity analysis shows that this finding is robust.

The results also show that, (1) there is no proof to suggest a significant relationship between complexity and effectiveness in any direction, (2) the relationship between complexity and acceptability is positive and the relationship is statistically significant; acceptability increases as complexity increases, from the perspective of the public and (3) effectiveness parameter of the utility function is estimated to be significantly higher than the acceptability parameter, from the perspective of policy makers

Implications of the results for policy design is that: policy makers should favor congestion charging plans with higher complexity levels; they should have a good relationship with the media and use them to explain the essence of the charging plan and the reasoning behind the chosen complexity level as clearly as possible to the public.

Further research can be performed on the relationship between policy objective and effectiveness, because the results hint that policy objective is an important factor that influences effectiveness, and without accounting for policy objective, the relationship between complexity and effectiveness cannot be clearly assessed. Another research can be performed on estimating how certain dimensions and sub-levels of those dimensions actually contribute to the level of complexity; in this thesis research, it was assumed that each dimension and its level contribute equally to the complexity. With such a research, a better definition of complexity levels can be made.

Keywords: Charging complexity, congestion charges, public acceptability, reduction in congestion, effectiveness, stated choice experiment, rating experiment, MNL model, regression analysis, social norms, perceived effectiveness, personal outcome expectations, policy

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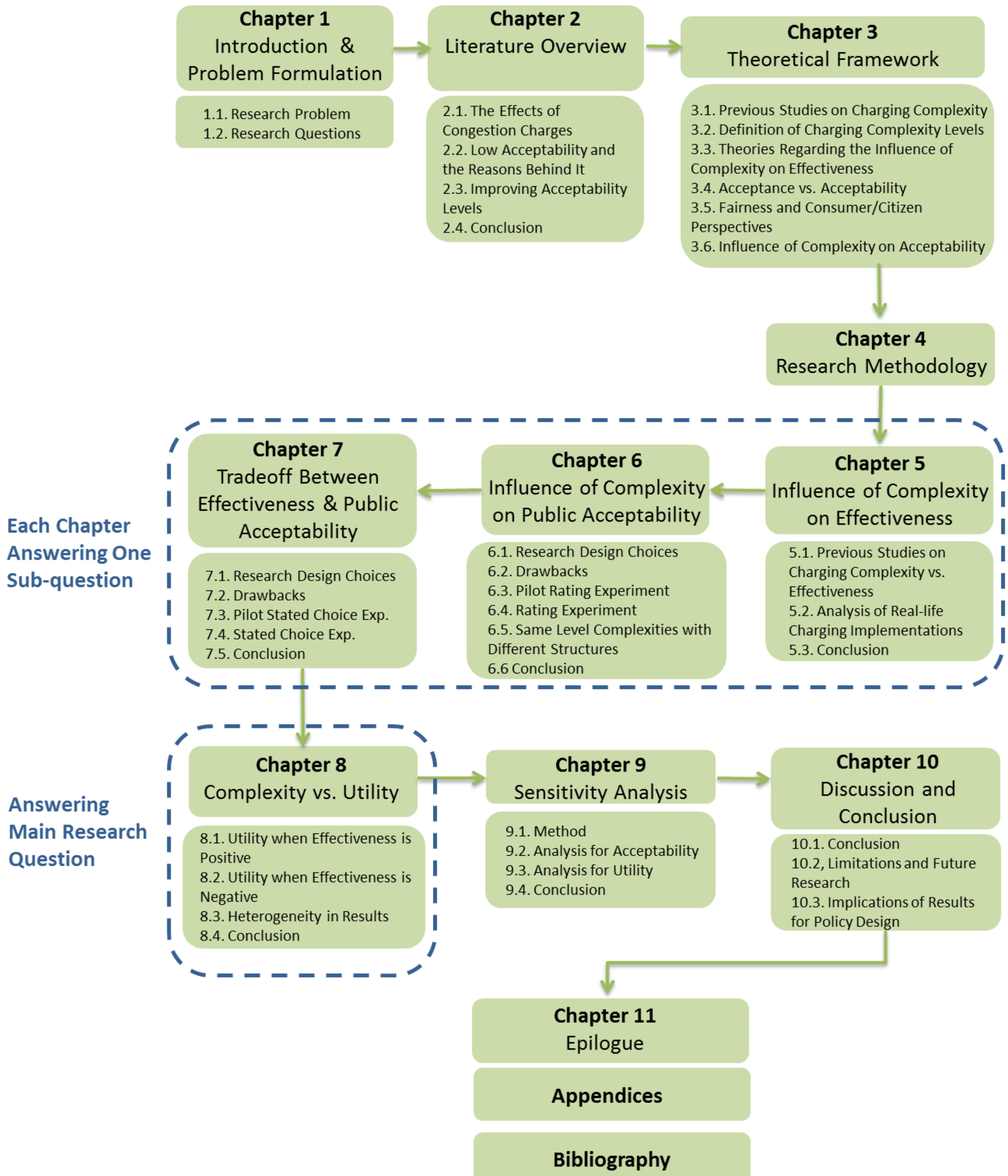
OUTLINE OF THE THESIS



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1. Introduction

Congestion charging is acknowledged as an efficient measure in tackling with traffic congestion and pollution (Börjesson & Kristoffersson, 2014). One of the main obstacles to the implementation of congestion charges is low public acceptability (Schade & Schlag, 2003). The factors affecting the level of acceptability have been well researched in literature. Schade and Schlag (2003) discuss that those factors that have a dominating influence on acceptability are mostly psychological; the most important and influential factors of those being the social norms, personal outcome expectations and perceived effectiveness. A study done by Fürst and Dieplinger (2014) reveal that these three factors account for more than 50% of the criterion variance. Another presumptive factor is charging complexity. Link (2015), in his paper on perception of pricing complexity by drivers, states that charging complexity decreases the resistance to considering behavioral changes which can be explained by ambiguity avoidance. This can be interpreted in a way that if the congestion charging is too complex, drivers will tend to not get involve with it, therefore reducing the congestion at the targeted area. However, Link (2015) also admits that some of the literature provides evidence against this, saying that if things get too complex, people might tend to stick with the status quo. Nevertheless, it is clear that charging complexity influences the effectiveness of congestion charging, but the nature of this influence is not clearly known. While charging complexity influences the effectiveness of congestion charging, it is imperative that it also influences public acceptability, because the issue of complexity is related to perception and thus to the factor of perceived effectiveness. It is not clear though how much or in what direction charging complexity influences public acceptability. From this stand point, the motivation of this thesis research is to dig further into the influence of charging complexity on first the effectiveness of congestion charging and second public acceptability with the objective of defining the relationship between charging complexity level and utility based on those two attributes, from the perspective of policy makers. In this this thesis research, utility is defined as the measure of usefulness of congestion charging plans for policy makers. A higher utility is perceived to yield a better outcome. Consider a utility for policy makers, that is based on effectiveness and public acceptability; if both effectiveness and acceptability are influenced by charging complexity levels, how would utility be affected by charging complexity levels? This thesis research aims to convert this utility function to a function of complexity levels and give an answer to this question.

Research problem is explained in Chapter 1.1. and the research questions are presented in Chapter 1.2. The literature overview that led to the motivation for this research is given in Chapter 2. Theoretical framework is given in Chapter 3 and research methodology is given in Chapter 4. There are three sub questions that originate from the main research question. These individual questions are addressed respectively in Chapter 5, 6 and 7. In Chapter 8, all the results from sub questions are brought together and the main research question is answered. Sensitivity analysis is performed in Chapter 9, and finally the discussion on limitations, the conclusion to the whole thesis research and implications of results for policy design are given in Chapter 10. Epilogue which contains my personal reflection to the thesis research is given in Chapter 11.

1.1. Research Problem

1.1.1. Problem Exploration

In order to define congestion charging complexity levels, first the notion of complexity must be defined. What makes a congestion charge too complex? In the literature, there are several factors defined which tends to increase complexity. These factors are explained in Chapter 3: Theoretical Framework. Based on these factors, a definition of complexity levels is made and thus complexity levels of a congestion charging plan can be estimated.

As mentioned in the literature overview, charging complexity is assumed to influence the effectiveness of the congestion charging. The effectiveness of the congestion charging refers to the reduction in traffic volume during charging hours; meaning that a decrease in the number of vehicles entering the congestion zone increases the effectiveness of the congestion charge. Therefore, the effectiveness of the congestion charge can be measured by comparing the congestion levels prior and posterior to the implementation of the congestion charge. It is ambiguous in which way the complexity influences the effectiveness; however, there are two concepts / theories on this issue. First, there is the theory of ambiguity avoidance. Ellsberg (1961) suggests that uncertainty of prices – for instance due to high charging complexity – pushes people to choose an option with a known price. This means that a high charging complexity could force people to avoid the congestion zone, make them choose an alternative path with a better-known price, thus increasing the effectiveness of the congestion charge. Second, there is the concept of status quo. Swait and Adamowicz (2001) suggest that increasing complexity produces more adherence to the status quo. When people face complexity continuously, they tend to focus less on attributes (such as the factors affecting complexity e.g. time, location, distance, payment, etc.) and the propensity to avoid choice increases. This means that instead of choosing an alternative path when faced with high charging complexity, people will instead start caring less about the consequences and keep entering the congestion zone, because they want to avoid decision making and thus the effectiveness of the congestion charge will decrease.

The influence of charging complexity on public acceptability is underrepresented in the literature; and it remains one of the objectives of this research to find out how much and in what direction that influence is. Once the influences of charging complexity on effectiveness and public acceptability have been estimated, the relationship between charging complexity and utility – from the perspective of policy makers – in terms of effectiveness and public acceptability can be determined.

1.1.2. Knowledge Gaps

Based on the problem exploration in Chapter 1.1.1., the following knowledge gaps are identified.

- It is not known how much and in which direction charging complexity influences the effectiveness of the congestion charging.
- It is not known how much and in which direction charging complexity influences the public acceptability levels.
- The relationship between congestion charging complexity level and utility in terms of effectiveness and public acceptability is not known.

1.1.3. Problem Statement

Concluding, the problem statement is:

> There is no determined relationship between congestion charging complexity level and utility that is based on the effectiveness and the public acceptability level of a congestion charge.

1.1.4. Research Objective & Deliverables

Based on the problem statement, the following research objective is formulated.

> The research objective is to determine the relationship between congestion charging complexity level and utility that is based on the effectiveness and public acceptability level of a congestion charge from the perspective of policy makers.

The expected deliverable of the project is a utility function that is based on charging complexity levels which the policy makers can use while constructing a future congestion charge implementation.

1.1.5. Scientific Relevance

The scientific relevance of the research is to figure out the influence of congestion charging complexity on public acceptability and the effectiveness of congestion charging. Since this area of research is underrepresented in literature, it will also provide vital information as being a reference study for other researchers who are studying congestion charging implementations and working on issues like acceptability and road pricing in other cities around the world.

1.1.6. Societal Relevance

The social relevance of the research lies in the objective which is to determine which charging complexity levels give a higher utility for the society. The objective serves the purpose of easing congestion charge implementations and increasing their utility based on effectiveness and public acceptability; therefore, reducing congestion levels and also pollution in a way that the society benefits the most. Reducing congestion levels is important for people living in congested cities, because high congestion levels present a serious threat to the economic growth of cities; also reducing pollution through reducing congestion prevents people from being subjected to poor air quality and thus making a positive impact on public health (“Reducing Congestion,” 2016).

1.2. Research Questions

Based on the problem statement/definition in Chapter 1.1., the following main research question is formulated:

> **What is the relationship between congestion charging complexity levels and utility in terms of the effectiveness of the congestion charge and the public acceptability level, from the perspective of policy makers?**

The following sub questions are formulated which help answer the main research question:

1. How much and in which direction does charging complexity influence the effectiveness of the congestion charging?
2. How much and in which direction does charging complexity influence the public acceptability levels?
3. What is the trade-off between the effectiveness of congestion charging and the public acceptability level?

In addition to answering these questions, I will also discuss the implications of the results for policy design.

2. Literature Overview

The purpose of the including the literature overview in this chapter of the thesis is to give the reader a background on the issues of congestion charging implementations, effectiveness and acceptability, and to show the reader how the research question of this thesis was formed based on the scientific gaps found through this literature overview.

Congestion charging refers to imposing a daily charge for cars driving in certain parts of a city in order to reduce traffic and to combat pollution; and it is generally acknowledged that it is an effective measure in tackling with those issues (Börjesson & Kristoffersson, 2014). A proof of that effectiveness can be seen in the implementation of congestion charges in London, Stockholm and Singapore which have reduced the traffic and improved the environment (Fürst & Dieplinger, 2014). However, congestion charging faces with low acceptability amongst the public in almost all cases and the lack of public acceptability is one of the main obstacles to the implementation of such charges (Schade & Schlag, 2003). For instance, in a referendum for applying congestion charges in Edinburgh in 2005, more than 74% of the voters have voted against such charges (Hensher & Puckett, 2005).

The literature overview is aimed at finding what the current state of congestion charge implementations is and which research areas can further be identified for the issue of acceptability levels. Several academic search engines such as Scopus, Google Scholar and Science Direct were used to find articles on the issues of congestion charges, road pricing and acceptability. The collection of articles was further extended with the inclusion of articles found via the references of the articles in the primary search. The following keywords were used.

Keywords: Congestion charging, acceptability, road pricing, perceived effectiveness, charging complexity.

The current state of congestion charge implementations refer to; first the effects of previously implemented charges on congestion and reducing pollution which is discussed in Chapter 2.1.; and second the reasons behind low acceptability levels in past and possible future implementations which is discussed in Chapter 2.2. Once the current state has been established, literature on improving acceptability levels is discussed in Chapter 2.3. Finally, the conclusion of the literature overview and the identified research areas based on that are discussed in Chapter 2.4.

2.1. The Effects of Congestion Charges

Congestion charging is an efficient means to reduce congestion since it has been proven so by its implementation in Singapore (1995), Rome (2001), Durham (2002), London (2003), Stockholm (2006), Valetta (2007), Milano (2008) and Gothenburg (2013) (Börjesson, Eliasson, Hugosson, & Brundell-Freij, 2012). There are a handful of cities that have implemented congestion charges and amongst those, detailed analysis of traffic effects have only been published for Singapore, London, Stockholm, Milan and recently Gothenburg (Börjesson & Kristoffersson, 2015). A study on Gothenburg which have implemented congestion charges in 2013, show that the short term effects are immediate, reducing the congestion by 12% within a year (Börjesson & Kristoffersson, 2015). Another study on the long term effects of congestion charges in Stockholm, reveal that the effects of the charges have increased slightly over time even though the initial expectation was that drivers would adapt to charges and the effects would wear off (Börjesson et al., 2012).

A research performed by Green, Heywood and Navarro (2016) reveal that after the implementation of congestion charges in London, among reduced congestion, accident rates, travel time and air pollution were also reduced, and travel reliability have increased. Accident reduction does not only apply for cars, but also applies for bikes, and it is concluded that bike riding became safer in London after the implementation of the congestion charge policy (Green et al., 2016).

The relationship between congestion charging and the public transport system, and how they affect each other is investigated in depth by Börjesson et al (2014) in their paper 'Not invented here: Transferability of congestion charges effects'. They take the implementation of congestion charges in Stockholm as their case and play with variables within the local transport system in order to see how volatile the benefits of congestion charges are to those changes. Contrary to general expectation, it is found out that the effects and benefits of congestion charges are not that sensitive to specific local features of the transport system (Börjesson et al., 2014). This suggests that the experiences of cities which implemented congestion charges are transferrable; and these experiences may as well be used when designing a new system without the doubt about whether local features have a significant impact or not. One remark they make is that the state of public transportation has almost no effect on reducing congestion; meaning that improving public transport substantially will only have a small effect on reducing congestion which is not worth the effort. They conclude that the most important variable that determines the benefits obtained from congestion charges is the initial congestion level.

Another finding by Börjesson et al (2014) is that drivers who are subjected to congestion charging tend to change mode more than changing route or destinations in Stockholm. This falls in line with the findings of Green, Heywood and Navarro (2016) in London which is that congestion charging is a successful mechanism to move travelers out of automobiles and into the public transportation system.

2.2. Low Acceptability and the Reasons Behind It

Among demand management measures, implementing congestion charges has one of the least public acceptability levels with only 14%, whereas other measures like improving public transport has 96%

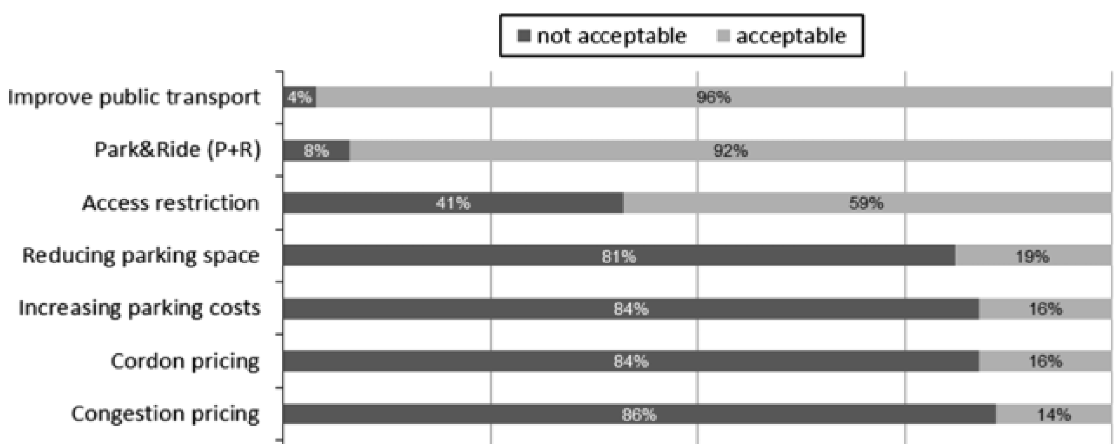

Figure 2: Acceptability of various travel demand management measures. Source: Fürst and Dieplinger(2014)

acceptability as seen in Figure 2 (Fürst & Dieplinger, 2014). Schade and Schlag (2003) discuss that the factors that have a dominating influence on acceptability are mostly psychological, the most important and influential factor of those being the social norms. Therefore, low acceptability of congestion charges is more directly related with negative social perception rather than the fee levels and other economic benefits. Schade and Schlag (2003) also mention of two other factors which are influential: personal outcome expectations and perceived effectiveness. These three factors in total were used in a research that tried to measure the current acceptability levels in Vienna by Fürst and Dieplinger (2014). The results of that research also confirm that there is low acceptability amongst the public when it comes to congestion charges; in fact they measure that the acceptability levels in Vienna are even lower compared to the situation in London before the implementation of congestion charges back in 2003 (Fürst & Dieplinger, 2014). Fürst and Dieplinger's (2014) research also confirm that social norms, personal outcome expectations and perceived effectiveness are the most influential factors, which account for more than 50% of the criterion variance. However, Fürst and Dieplinger's (2014) research reveal that personal outcome expectation is by far the most influential factor whereas Schade and Schlang (2003) stated that social norm was the most influential one. This small difference can be caused due to the differences in cities where these researches were conducted. Schade and Schlang (2003) conducted their research in four cities: Como, Athens, Dresden and Oslo whereas Fürst and Dieplinger (2014) remained limited within Vienna.

One remark is that both the research by Schade and Schlang (2003), and Fürst and Dieplinger (2014) used data retrieved from drivers and motorists; therefore Fürst and Dieplinger suggest that acceptability levels can be significantly higher if the entire population is concerned including non-drivers.

Börjesson and Kristoffersson (2014) discuss that one of the other possible reasons for low acceptability is the notion that drivers are worse off if they are not compensated by the revenues. This finding falls in line with the psychological factors mentioned by Schade and Schlag (2003) in the sense that drivers perceive the effectiveness of congestion charges negatively. According to Börjesson and Kristoffersson (2014), this notion has been previously proven by a standard textbook analysis and a traffic model called Sampers in 2011; however they suggest that the Sampers model and the standard textbook analysis did not consider three important factors: network effects, adaptability of drivers and heterogeneity in value of travel time. Taking these factors into account, Börjesson and Kristoffersson (2014) come to a new conclusion that drivers actually benefit from congestion charges even without being compensated by revenues. This finding suggests that the previous widely accepted notions or social norms can be proven wrong.

2.3. Improving Acceptability Levels

Börjesson et al (2012) state in their paper on the long term effects of congestion charges in Stockholm that political acceptability and public acceptability should be separated from each other. They state that public acceptability is neither a necessary nor a sufficient condition for political acceptability (Börjesson et al., 2012). Therefore, even though the public acceptability is low, congestion charges can be implemented, assuming that it is not voted by the public e.g. in a referendum. Back in 2006, when the congestion charges started to apply in Stockholm, public acceptability was low; however it increased immensely over the long term. One of the most important reasons for improved public acceptability seems to be the observation and the discovery over time by the public that the charges are effective in reducing congestion and also emission levels (Börjesson et al., 2012). This is directly related with the psychological factors defined by Schade and Schlang (2003) and proves the assertion that social norms can be changed in a favorable way towards congestion charging. Therefore with a campaign that is directed at changing the perception of the public by emphasizing the actual effects of congestion charges with proofs from previous examples, public acceptability can be improved. On the issue of political acceptability, Börjesson et al (2012) suggest that it can be increased via giving regional politicians more power over the use of the revenues, therefore integrating the charges into the national investment process.

Hysing and Isaksson (2015), in their paper which discusses the experiences of Stockholm and Gothenburg in terms of acceptability, state that improving public transport system during the trial period in Stockholm have increased public acceptability. However, in Gothenburg where public transport was not improved substantially and was already weak due to the car-based lifestyle, the acceptability was lower. They conclude that in order to improve acceptability levels, the concept of congestion charging needs to be placed in its local ideological and political context.

Link (2015), in his paper on perception of pricing complexity by drivers, states that charge complexity decreases the resistance to considering behavioral changes which can be explained by ambiguity avoidance. This can be interpreted in a way that if the congestion charging is complex, drivers will tend to not get involve with it, therefore reducing the congestion at the targeted area. However, Link also admits that there is some evidence against this as well. The complexity of the charging scheme would also intuitively influence public acceptability, since previous findings suggest that a clear and well-designed plan can influence acceptability levels, and complexity is a part of the design plan. The ideal level of charging complexity remains ambiguous, it is under-researched in literature.

A study done by Zheng et al (2014) show that lower congestion charges (among the proposed ones), lower travel times and lower bus fares for transit users (as a direct benefit from the revenue collected through congestion charges) increase the level of support and thus acceptability for implementing a congestion charge. A higher congestion charge is regarded by drivers as an infringement of their personal freedom and therefore results in a lower acceptability (Zheng et al., 2014). They also state that the congestion charge’s contribution in protecting the environment by reducing vehicle emissions also has a significant impact on acceptability: if the contribution is high, acceptability increases and vice versa (Zheng et al., 2014). A very interesting finding in the same study is that congestion charge’s role in reducing the congestion has no significant effect on acceptability. This finding actually implies that perceived effectiveness is an important factor at influencing acceptability rather than the actual effectiveness of the charge which in this case is to reduce congestion. This also falls in line with the findings of Fürst and Dieplinger (2014), and Schade and Schlang (2003) on the significance of perceived effectiveness. Zheng et al (2014) discuss that the perceived effectiveness is also directly related to how the congestion charge is promoted. For instance, if the primary goal is to reduce emission, then the perceived effectiveness will focus on reducing emission and reducing congestion will become insignificant (as it did in Zheng et al’s (2014) study). Therefore, in order to increase acceptability, a congestion charge scheme needs to be designed and promoted to meet scheme concerns (Zheng et al., 2014). Another remark in the study is that, revenue distribution is also an important factor affecting acceptability. A well-established revenue distribution structure - such as transit/road infrastructure improvements – also increases acceptability.

2.4. Conclusion of the Literature Overview

The objective of the literature overview was to investigate the current state of congestion charge implementations and identify research areas for the issue of acceptability. The literature overview reveals that the effects of congestion charges and the issues of acceptability have been studied on a handful of cities, the spotlight being on Swedish cities, Stockholm and Gothenburg; and also on London as a successful example of congestion charge implementation. Congestion charging has proven to be effective in all cases according to the studies reviewed. The low acceptability level is seen as one of the most important obstacles for implementing a charging policy. The factors affecting the low acceptability level such as social norms, perceived effectiveness and social outcome have been researched in depth; however, there is limited or no study when it comes to issues such as finding a level of complexity which would give a high utility or determining how factors causing low acceptability can be used in a way to improve acceptability.

One of the possible research areas could be to determine how the level of charging complexity influences the utility of a congestion plan based on changes in the effectiveness of charging and changes in public acceptability; and based on this literature overview, for this thesis project, this research area was chosen. Findings of the literature overview, other than motivating the topic of this research, has also been used in structuring the rating and stated choice experiments which are performed in Chapter 6 and 7.

3. Theoretical Framework

3.1. Previous Studies on Charging Complexity

Polancic and Cegnar define complexity as “the degree to which a process is difficult to analyze, understand or explain”(Polančič & Cegnar, 2016). They state that complexity may be categorized by the intricacy of its characteristics. One of the most important researches that has been conducted about charging complexity is named the GRACE project: Generalization of Research on Accounts and Cost Estimation. The project started in July 2005, and took 30 months to complete. The project was commissioned and funded by European Commission as part of a program called the Sixth Framework. It was in partnership with the Institute for Transport Studies at University of Leeds. One of the deliverables of the project was a report titled ‘Optimal Complexity of Prices for Transport Infrastructure’. The research on optimal charging complexity consisted of surveys performed in 3 countries: UK, Germany and Greece. The aim of the research was to find an optimal complexity for pricing, they state that their definition of optimal is ‘most efficient’ (Bonsall, Shires, Ngoduy, et al., 2007). They define the following five factors that tends to increase complexity:

“(1) The number of dimensions on which the charges vary (e.g. time, location, type of vehicle, date of payment, method of payment……); (2) the number of charge levels in each dimension; (3) the extent of any calculations required to estimate the charge (e.g. is the relevant charge fixed, or, if it is a function of one or more variables, is that function linear, geometrical, piecewise, arbitrary or composite?); (4) the number of discounts and exemptions; and (5) the total number of charge levels to which a given user might be subject (i.e. excluding dimensions or discounts which are obviously not relevant for that user).“ (Bonsall, Shires, Ngoduy, et al., 2007, p. 5).

Bonsall et al. (2007) did not structure different complexity levels based on these factors; instead they did the following: In the surveys, they presented respondents with one of the three charging plans (all three were regarded as similarly complex by researchers) and asked them (1) how easy it was for them to predict charges and (2) how would they behaviorally respond to it. Based on the answers from respondents, they created a logit model and tested responses to 4 different simple charging plans and 1 fully complex charging plan (which varied on location and type of vehicle) in a hypothetical city, they called the ‘test’ city. Then they compared the simple charging plans with the one fully complex charging plan. Therefore, their definition of complexity was limited to only two levels: either simple or fully complex; and it was based on the perspective of the respondents.

Link (2015) performed a similar research in Cologne and Frankfurt. That research consisted of 5 different charging plans which varied in terms of the area covered and the structure of the charge (time periods, cost variance etc.). Those 5 different complexity charges were deliberately similarly complex. Link (2015) used the same methodology as Bonsall et al. (2007) and asked the respondents (1) how easy it was for them to predict the charges and (2) how they would behaviorally respond to it. Link (2015)’s aim was not to estimate an optimal complexity, but to see behavioral responses to different perceptions of complexity; so her research does not go into modelling of responses in an hypothetical environment like the GRACE project. Similarly, Link (2015)’s research defines complexity based on responses from the survey.

Bonsall et al. (2007) conclude that they could not explore exactly what makes one price signal more complex than another. Both the GRACE project and more recently Link (2015)’s research could not create a sound definition for different charging complexity levels. Therefore, it is not the aim of this thesis research to come up with a sound definition for charging complexity levels when multiple researchers could not do it in much larger time scopes with funding that I don't have. However, there is a need for a definition of charging complexity levels which I will use in this thesis research in order to be consistent in my investigation of how complexity influences effectiveness and acceptability.

3.2. Definition of Charging Complexity Levels

Defining different complexity levels based on responses from a survey requires a whole another research on itself. In addition, those complexity levels will be only applicable to the respondents of that survey. There will be different perceptions of complexity in different cities, countries and cultures. For this thesis research, a definition for complexity is needed such that higher levels of it will be objectively more complex than the lower levels.

In order to create a definition for complexity levels, I used the factors that increase complexity as mentioned in the GRACE project. Among those factors, 'the total number of charge levels' is inclusive of all the other factors, because it is related to the dimensions, their separate levels and the exemptions/discounts as a whole within itself; and higher total number of charge levels would intuitively lead to more calculations required to estimate the charge, so it includes that factor as well. In my understanding, the total number of charge levels gives an objective judgement of the level of complexity of a charging plan.

Three attributes were identified that make up the complexity level: (1) number of dimensions, (2) number of levels in each dimension and (3) number of levels of exemptions and discounts**. The complexity level equals to the sum of number of levels in dimensions plus the number of levels of exemptions and discounts.**

Successfully implemented congestion charging plans were investigated case by case (see Appendix I) and six different dimensions were identified: time, cost, location, type of vehicle, method of payment and date of payment.

The levels within the dimensions of the congestion charge present an issue in regards to their weight at affecting the complexity. For instance, let's assume there are only two time intervals in a congestion charge (also called a daily charge, e.g. charge between 08.00 – 18.00, and no charge in other hours); if the number of intervals were increased to ten, would it increase the complexity by fivefold? There is no literature on this issue; however, based on instinctive decision making process that we all perform, it would be logical for a decision maker to differentiate between two kinds of time intervals only: whether it is a daily charge or a multi-interval charge. Therefore, it is assumed that if there are multiple time intervals in a congestion charge compared to a daily charge, it would increase complexity just by one level. Nine time intervals, compared to ten time intervals would make no difference in terms of the complexity. This notion is applied to other dimensions as well. If there was no variance for the dimension, the level was set to 1, if there were variance for the dimension, the level was set to 2.

There is a similar issue for the number of levels of the exemptions/discounts in the charge. Possibly, each individual exemption can be considered a level and increase the total complexity level. For instance, if a congestion charge had exemptions for Saturdays and Sundays; this could add 2 levels to the total complexity. However, if the wording is changed, and we use 'weekends', instead of Saturday and Sunday, then we only need to add 1 level to the total complexity. The interpretation of the charge can irrationally increase the complexity. In order to prevent this, the levels within exemptions/discounts are to be counted not as individual exemptions, but as categories. For instance, if there is an exemption on Saturdays, Sundays and during Christmas; they are categorized as 'day exemptions' and only add 1 level to the total complexity level.

Consequently, the following legend was created to define charging complexity levels. This definition of complexity levels only applies to this thesis research.

Table 1: Definition of Charging Complexity Levels

Dimension	Levels
Time	If there is a daily charge, meaning that there are only two time intervals (e.g. charge between 08.00-18.00, and no charge in other hours), complexity increases 1 level. If there are more than two time intervals, complexity increases 2 levels.
Cost	If the cost is fixed, complexity increases 1 level. If the cost varies, complexity increases 2 levels.
Location	If the charge applies in one location, complexity increases 1 level. If the charge applies in multiple locations, complexity increases 2 levels.
Type of vehicle	If there is no differentiation among types of vehicles, complexity increases 1 level. If there is a differentiation among types of vehicles, complexity increases 2 levels.
Method of Payment	If there is only one method of payment, complexity increases 1 level. If there are multiple methods of payment, complexity increases 2 levels.
Date of Payment	If there is only one date of payment, complexity increases 1 level. If there are multiple dates of payment, complexity increases 2 levels.
Level of Exemptions / Discounts	
Each category of exemption / discounts will increase the complexity level by 1.	

An example of this definition is given below for the congestion charging implementation in Stockholm.

Table 2: Complexity Level of Stockholm Congestion Charge

Dimension	Explanation	Number of Levels
Time	There are 10 time intervals per day.	2
Cost	The charges applied are either 10 SEK, 15 SEK or 20 SEK.	2
Location	Charges apply only in one area.	1
Type of Vehicle	There is no differentiation between type of vehicles except the ones in the exemptions.	1
Method of Payment	There is no immediate method of payment.	-
Date of Payment	Payment must be made later, within one month after the payment slip for that month is delivered. There are no different payment schemes, e.g. paying for 3 months at once, or paying yearly etc.	1
Exemptions / Discounts		

Day exemptions: No charges on Saturdays, Sundays, public holidays or a day before such holiday. Vehicle exemptions: Taxis, buses, eco-fuel cars, emergency vehicles, EC mobile cranes, motorbikes and mopeds are exempt. Road exemptions: Essinge bypass and the bypass traffic from and to the island of Lidingö are exempt. There are 3 categories of exemptions in total. There are no discounts.	3
Complexity Level (Total number of levels)	**10**

According to the definition of charging complexity levels in this thesis research, Stockholm Congestion Charge has a complexity level of 10.

This creates a structured definition for complexity, but on the other hand allows two completely different cases with different dimensions and levels to fall under the same complexity level. For instance, two dimensions with each three levels would give a level six complexity; similarly, three dimensions with two levels each give the same level of complexity (excluding exemptions or discounts). This is unavoidable; however, this problem will be addressed in Chapter 6 where the relationship between complexity levels and acceptability is determined. In summary, this is how the problem is addressed: In Chapter 6, a rating experiment is performed and based on the rating experiment, it is figured out how public acceptability differs as the complexity changes. In that rating experiment, number of dimensions, levels and exemptions/discounts are used as attributes. A multiple regression analysis is made using the data from the rating experiment. This gives us information about the weights of attributes in influencing the acceptability. Based on this, it is possible to differentiate between two same-level complexities in regards to their acceptability levels.

3.3. Theories Regarding the Influence of Complexity on Effectiveness

Effectiveness and in what context it is used must also be defined. In this research, effectiveness is the percentage of reduction in congestion. The reference time span for the effectiveness is the first 6 to 12 months after implementation, also called as the ‘immediate’ effectiveness.

As mentioned in Chapter 1.1.1. Problem Exploration, there are two theories about the influence of complexity on effectiveness. The first theory is the theory of ambiguity avoidance. Ellsberg (1961) explains ambiguity avoidance as such that uncertainty of a price pushing people to choose an option with a known price. Aloysius (2005) describes ambiguity as a second order uncertainty or uncertainty about uncertainty. First order uncertainty is about uncertainty over overcomes, e.g. not knowing how to act when a certain outcome occurs. Second order uncertainty also includes the uncertainty about the probabilities at which the outcomes can occur (Aloysius, 2005). Therefore, Aloysius describes ambiguity avoidance as “the propensity displayed by decision makers toward the avoidance of that uncertainty about uncertainty”(Aloysius, 2005). Applying this definition to our research; ambiguity avoidance occurs when the decision maker is uncertain about the dimension of a congestion charge, and is also uncertain about the levels within that dimension. For instance; if a decision maker is uncertain which time slots apply for his/her vehicle, and is also uncertain how much he/she needs to pay within that time slot; then there is ambiguity, and the decision maker can choose to avoid decision making by not involving himself/herself in the congestion charging zone. Link (2015) states that ambiguity avoidance might be the reason behind why the probability of considering behavioral changes increases while the charging complexity increases.

An increase in the probability of considering behavioral changes means that people avoid the congestion zone. This is based on the remarks of Börjesson et al. (2014) that when people perform behavioral changes, they tend to change the mode more than the destination or the route, thus for a car driver, it means that he/she no longer gets inside the congestion zone with his/her personal vehicle, but rather most likely through public transport. The base assumption Link (2015) makes is that charging complexity and ambiguity are directly proportional, so an increase in complexity also results in an increase in ambiguity. Overall, the theory of ambiguity suggests that while complexity increases, ambiguity avoidance increases, and therefore effectiveness also increases.

The second theory is the theory of status quo effect/bias. Riella and Teper (2014) describe status quo bias as a phenomenon where individuals have a strong tendency to retain the current state of affairs. In relevance to our research, the status quo refers to the current route of the decision maker. “The decision maker considers an alternative choosable only if its chances of incurring a (subjectively) severe loss, relative to the status quo, are not too high.” (Riella & Teper, 2014). Swait and Adamowicz (2001) state that increasing complexity causes more adherence to the status quo, thus triggering status quo effect. Decision makers become more biased towards other alternatives and they avoid decision making entirely, thus sticking with the status quo. Theory of status quo bias suggests that while complexity increases decision makers will stick with the current route, thus getting into the congestion zone and decreasing the effectiveness. In this research, the financial benefits of the congestion zone due to charge collections are ignored, since the definition of effectiveness is limited to reduction in congestion and does not include economic benefits.

The two theories explained above provide different expectations about the influence of complexity on effectiveness. Therefore, the expected influence of complexity on effectiveness itself is ambiguous.

3.4. Acceptance vs. Acceptability

A terminological difference must be made between acceptance and acceptability. Acceptability refers to the attitude on road pricing schemes before the implementation whereas acceptance refers to the attitude after the implementation (Schuitema, Steg, & Forward, 2010). In the entirety of this thesis research, the term acceptability is used. In some instances, instead of ‘acceptance’, the term ‘acceptability after implementation’ is used.

3.5. Fairness and Consumer’s Perspective vs. Citizen’s Perspective

What is fair in terms of road pricing has long been a topic of discussion. Eliasson (2016) states that there is no objective way to measure or define fairness. Researches use socio-economic groups as reference and try to see how much they pay for road prices as a share of their income. Based on this share and comparing it amongst socio-economic groups, they interpret fairness. For instance, in a road pricing system, it would be fair if low income groups pay a lower share, whereas high income groups would pay a higher share. Eliasson (2016) describes that there are two perspectives from which fairness of a congestion pricing can be explored: consumer’s perspective and citizen’s perspective. The consumer’s perspective concerns how an individual is affected personally; how much he/she pays, how much time he/she saves etc. The citizen’s perspective on the other hand, is about a more social perspective, disregarding a person’s self-interest and focusing more on what the individual sees as ‘fair’ for the society

(Eliasson, 2016). Consumer's perspective is the traditional perspective on fairness in equity analysis (Eliasson, 2016).

In this thesis research, **the main research question is answered from the citizen's perspective (policy maker's perspective).** Intuitively I assume that a policy maker would behave from a citizen's perspective and try to do what is good for the society as a whole. The utility function that provides the answer to the main research question has two parameters: parameter for effectiveness and parameter for public acceptability. In Chapter 7, a stated choice experiment is performed to estimate those parameters. In the stated choice experiment, the respondents are asked to put themselves in the shoes of policy makers. Therefore, the parameter estimates represent the perspective of policy makers which is similar to the citizen's perspective.

On the other hand, sub questions regarding the relationship between (1) complexity and effectiveness and (2) complexity and public acceptability are answered from **the consumer's perspective**. A rating experiment regarding the acceptability of certain congestion charging plans is performed in Chapter 6. That experiment focuses solely on the consumer's perspective, since it relies heavily on self-interest variables such as time, location, payment method etc. of the plan.

Regarding the relationship between complexity and acceptability, I acknowledge that the concept of fairness can be an influencing factor. A higher complexity level might present a fairer situation from the consumer's perspective.

I would like to explain this with the following example. Let's assume that we present a person two charging plans: plan A with 75 different charges varying on several dimensions and plan B with 10 different charges varying on similar dimensions. Plan A is more complex than plan B; any sane person with a logical thought process would arrive at this conclusion. If we ask that person, which plan is more complex based on predicting the charges, s/he will logically respond that plan A is more complex. Then if we ask that person which plan s/he thinks is more acceptable, she will be inclined to say plan B is more acceptable, because she can more easily predict charges in plan B. Now, if from the beginning, we don't ask that person about which plan is more complex, but if we just ask which plan is more acceptable; then s/he might respond that plan A is more acceptable because it is more fair. In this thesis research, the respondents are **not** asked to define the complexity of a charging plan, therefore the effect of fairness can outweigh the labor of predicting charges.

3.6. Influence of Complexity on Acceptability

There is a great deal of material in the literature when it comes to factors affecting acceptability. However, the factor of complexity and specifically the relationship between complexity and acceptability is extremely under-researched. In fact, I have come across only a few articles that hints at this relationship: (Grisolía, López, & Ortúzar, 2015) and (de Palma, Lindsey, & Proost, 2007). Both papers only barely mention complexity, and they argue that increasing complexity causes dislike and rejection. They do not use the word 'acceptability'. The references, for instance de Palma et al. (2007) provide for this 'dislike' and 'rejection' come from the following study: (Department for Transport, 2004). That study is based on survey data, similar to the GRACE project and the dislike is connected to the difficulty of predicting charges in higher complexities. The pre-requisite for this 'dislike' is that respondents are asked to identify the complexity of a plan, which creates a negative perception for higher complexities. However, in real-life we would not expect respondents to define the complexity level of a charge plan. In this thesis research, the respondents are asked to rate the acceptability of a charging plan without being asked to define complexities. This approach will also provide an insight to whether fairness can outweigh the labor of predicting charges as mentioned in the previous section.

4. Research Methodology

The research methods that were used to answer the first sub question '*How much and in which direction does charging complexity influence the effectiveness of the congestion charging?*' are desk research and regression analysis. Desk research consisted of finding previous studies that looked into the relationship between charging complexity and effectiveness; and also investigating real-life congestion charging implementations. Subsequently, a regression analysis of the observations regarding to this relationship from real-life congestion charging implementations is made. For the desk research, Scopus and Science Direct were used to find articles. The keywords I used were: congestion charging, road pricing, effectiveness and reduction in congestion. Congestion charge implementations around the world were investigated in depth and their complexity levels were categorized. Using regression analysis, the relationship between complexity and effectiveness in real-life charging implementations were interpreted. Minitab statistical software was used to perform the regression analysis.

The research methods that were used to answer the second sub question '*How much and in which direction does charging complexity influence the public acceptability levels?'* are rating experiment and regression analysis. Public acceptability is a complex variable, meaning that its value summarizes various other variables. In the rating experiment, it was used as a dependent variable to examine how a range of attributes affect public acceptability. Complexity attributes defined in Chapter 3.2. are also used as attributes in the rating experiment. Details about the attributes are given under 'Research Design Choices' in Chapter 6. Rating experiment was designed using Ngene software and the data from the experiment was analyzed in Minitab. A pilot experiment was performed before the main rating experiment. A rating experiment works like any other stated choice experiment; however instead of making a choice between given alternatives, the rating experiment is presented with one alternative and a rating scale for participants to rate the alternative.

The research methods that were used to answer the third sub question '*What is the trade-off between the effectiveness of congestion charging and the public acceptability level?*' are stated choice experiment and the analysis of that experiment through a MNL (Logit) model based on Random Utility Maximization. MNL model was chosen, because given the scope of this research and the number of parameters we have -which is only two: public acceptability and effectiveness-, a linear additive RUM model is convenient enough. In a research with a larger scope and more complicated parameters, a Mixed Logit Model or Random Regret Minimization Model could have been used. Details about the attributes of the stated choice experiment are given under 'Research Design Choices' in Chapter 7. Stated choice experiment was designed using Ngene software and the data from the experiment was analyzed in Biogeme. A pilot experiment was performed before the main stated choice experiment. Respondents were asked to make a choice between two alternatives of congestion charge implementations which differ in effectiveness and public acceptability level. A stated choice experiment aims to estimate the trade-offs that the respondents make between the attributes in that experiment by observing the choices between alternatives. The aim of a stated choice experiment is to estimate unbiased and reliable parameters.

The surveys for the rating and stated choice experiments were implemented both online and by hand. The link to the survey was e-mailed to academics who work at TU Delft. The link was also sent to friends, and published on my social network accounts (Facebook and Twitter). The survey was performed by hand at the campus of TU Delft and at the Student Hotel in Den Haag where I live. Those locations were chosen for their convenience in finding respondents easily.

The stated choice experiment is based on a utility function that is based on effectiveness and public acceptability. First sub question provides an effectiveness function based on complexity, second sub question provides an acceptability function based on complexity and the third sub question provides the parameters for effectiveness and acceptability. Using the results from sub questions, the utility function was converted to a function of complexity and the main research question was answered.

In addition, a sensitivity analysis was performed by investigating how the results of this research would change if only certain demographic groups from the experiments were taken as reference. Finally, implications of results on policy design were explored, limitations and future research areas were discussed and the report was concluded.

5. Influence of Complexity on Effectiveness

In this chapter, previous studies that looked into the relationship between charging complexity and effectiveness are investigated. Subsequently, an analysis of the observations regarding to this relationship from real-life congestion charging implementations is made. This chapter provides the answer to the first sub question: **How much and in which direction does charging complexity influence the effectiveness of the congestion charging?**

5.1. Previous Studies on Charging Complexity vs. Effectiveness

UK Department for Transport (DfT) commissioned a study in 2004 to design a national road pricing scheme. In that study, plans with different charge structures were compared in terms of their anticipated effectiveness with the use of National Transport Model which incorporated relevant survey data regarding behavioral changes of people. A scheme with 75 different charges in total that varied by the level of congestion, area and road type estimated a 48% reduction in congestion. Another scheme with 10 different charges in total that varied by same dimensions estimated a 46% reduction in congestion (Department for Transport, 2004). A scheme with 75 different charges is objectively more complex than a scheme with 10 different charges. Bonsall et al. (2007), in a paper regarding this study, state that there is a tendency of general aversion when it comes to complex prices. This finding supports the theory of ambiguity avoidance and show that there is a tendency that effectiveness increases in a more complex scheme.

Bonsall et al. (2007), in a different paper regarding the GRACE project, looked at the relationship between charging complexity and net benefits. Their definition of net benefits was similar to that of a cost-benefit analysis. They do, however, also investigate reduction of congestion (effectiveness) in their modelling. They conclude that the more complex schemes tend to have greater effectiveness levels. They also state that, in more complex schemes, when charges are difficult to predict, people show a tendency to avoid them. This finding also supports the theory of ambiguity avoidance mentioned in the theoretical framework.

Link (2015), in her study regarding drivers' response to congestion charging schemes in Frankfurt and Cologne, conclude that charging complexity decreases the resistance to considering behavioral changes, which, she says, can be explained by the theory of ambiguity avoidance.

All of the three studies mentioned above indicate a tendency that increasing complexity also increases effectiveness which the researchers explain by the theory of ambiguity avoidance. However, none of these studies provide a conclusive result. There is no significant proof among the result of these studies that can conclusively put an end to question of complexity's influence on effectiveness. Link (2015) states that further research is necessary to test the findings in order to cross out the theory of status quo.

5.2. Analysis of Real-life Congestion Charging Implementations Regarding Complexity vs. Effectiveness

All of the three studies mentioned in the previous section have the following feature in common: their models and results are based on survey data, hypothetical situations in which the respondents of surveys state how likely they would behave in such a situation. Bonsall et al. (2007) admit that this is not the same as observing people's actual responses in real-life situations.

In this thesis research, in order to investigate the relationship between complexity and effectiveness, I could have performed a survey that is similar to the one in the GRACE project and ask respondents how they would behaviorally respond to a charge plan in a hypothetical situation. However, that would just be repetition of the studies given above and it would not contribute anything new to the literature. In addition, GRACE project was a 30-month long project with multiple researchers and they could not arrive at a conclusive result; to think that I could come up with a conclusive result in 5-months would not be a realistic goal.

From this stand point, in order to investigate the relationship between complexity and effectiveness, an analysis of observations in real-life congestion charging implementations is made. I applied my definition of complexity levels to congestion charges in Stockholm, Gothenburg, London, Milan and Singapore. Then, those complexity levels were compared to the actual effectiveness of the congestion charges.

By doing an analysis of five observations, my intention is not to perform an inductive statistical analysis; moreover, five data points is nowhere near enough to perform such an analysis, let alone suggest a significant relationship as a result.

There are two motivations behind this analysis of real-life observations:

1. Complexity levels of real-life charging plans and actual effectiveness levels were never compared. Previous studies all relied on survey data and behavioral responses in hypothetical situations. That is heavily due to the fact that those previous studies focused on perceived complexity of charge plans which is limited to the sample of respondents in that survey. It is difficult to compare perceived complexities across different populations, because different populations have different perceptions. Whereas, in this thesis research, the definition of complexity level is intended to be objective; therefore, it is possible to compare different charging plans across different countries. However, there are also limitations in comparing objective complexities. In order to overcome some of those limitations, I take into account the effect of initial congestion level and the cost of the charges in my analysis; yet there might still be political or other reasons that influence effectiveness heavily. (see Appendix I).
2. Although inconclusive, there is a tendency towards the theory of ambiguity avoidance among previous studies. I wanted to see if there is such a tendency in real-life observations too.

The entire analysis of real-life observations is given in Appendix I. It includes (1) research design choices that shape the analysis, (2) drawbacks, (3) quantification of complexity levels in Stockholm, Gothenburg, London, Milan and Singapore and (4) regression analysis on the data. The results are discussed here.

The results of the regression analysis show that the regression equation is negative: effectiveness seems to decrease as complexity increases. This can be interpreted as leaning towards the theory of status quo effect rather than the theory of ambiguity avoidance, because in such a case decision makers would tend to retain current state of affairs in a higher complexity, thus not changing route or mode and entering the congestion zone as before, which in result decreases effectiveness and fits the result of the regression analysis. This result contrasts with the previous studies mentioned in the previous section. However, Swedish cities of Stockholm and Gothenburg act as outliers in some of the observations. For instance;

they have the same level of complexity, but there is a huge difference in their effectiveness level. If we exclude Swedish cities of Stockholm and Gothenburg from the analysis of observations, the result is completely reversed. Excluding Swedish cities, the analysis can be interpreted as leaning towards the theory of ambiguity avoidance, because in such a case decision makers would avoid using the congestion zone due to the uncertainty of prices, which in result increases the effectiveness.

In conclusion, one cannot say which theory actually precedes in real world circumstances, because there is no consistency in results; observing different cities gives different results.

Bonsall et al. (2007) state that behaviors of people show a tendency to be dependent on the objective of the congestion charging plan and how that plan was revealed to them. For instance, they advise that if the policy objective is to minimize congestion levels, then user's ability to understand the charging plan should be maximized. Looking retrospectively at the analysis of observations, the reason behind the difference in effectiveness between Stockholm and Gothenburg congestion charges can actually be the policy objective. (Stockholm had 22% decrease in congestion, whereas Gothenburg had 12%.) The policy objective in Stockholm was primarily to reduce congestion; however, the policy objective in Gothenburg was to reduce congestion and also equally important, to gather revenue for public investments. This difference in policy objective might have caused that significant difference in effectiveness. However, there is more research needed to conclusively state that there is a strong relationship between effectiveness and the policy objective.

5.3. Conclusion

The first sub question in this thesis research and the aim of this chapter was to determine the relationship between complexity levels and effectiveness; and the answer is that there is no proof to suggest a significant relationship in any direction, neither in previous studies or in real-life observations of congestion charging plans.

The literature leans towards suggesting that effectiveness increases as complexity levels increase; however, there is no conclusive results in any of the studies and these suggestions do not go past being 'tendencies'.

The implications of this result for this thesis research is the following: In order to convert the utility function to a function of complexity, there is a need to express effectiveness in terms of complexity. Since there is no conclusive result for the relationship between complexity and effectiveness; both possibilities are going to be taken into account. The utility is going to be investigated for both cases (1) a positive relationship between effectiveness and complexity and (2) a negative relationship between effectiveness and complexity. Recall that the analysis of real-life observations provided two contrasting results. The regression equations of those two results are going to be used as the effectiveness functions; those functions are based on the definition of complexity levels in this thesis research, so they would be consistent with the acceptability part of utility. The equations are given below. Derivation of these equations are given in Appendix I. (E for effectiveness and CL for complexity level).

$$(1)\ Positive\ relationship: \qquad E = 1.100 + 1.046\ CL$$
$$(2)\ Negative\ relationship: \qquad E = 25.67 - 0.9185\ CL$$

6. Influence of Complexity on Public Acceptability

In this chapter, a rating experiment is performed in order to figure out the relationship between complexity and public acceptability. This chapter provides the answer to the second sub question: **How much and in which direction does charging complexity influence the public acceptability levels?**

6.1. Research Design Choices

Based on the definition of complexity levels in Chapter 3.2., the following attributes are set for the rating experiment: (1) number of dimensions which the charges vary, (2) number of charge levels in each dimension and (3) the number of discounts and exemptions.

The first attribute – number of dimensions – is given two levels [0,1]. The first level will be referred as 0, and the second level as 1. 0 stands for 5 dimensions. 1 stands for 6 dimensions. The number of dimensions are decided based on the observations made during the case studies which are given in Appendix I. In all cases, the number of dimensions was either 5 or 6. When it was 5, in all cases, the missing dimension was 'method of payment'.

The second attribute – number of charge levels – is given two levels [0,1]. 0 means that only 1 level is assigned to each dimension. 1 means that 2 levels are assigned to each dimension. Based on the observations in Appendix I, the levels within dimensions were either 1 or 2.

Note: Normally, each dimension can have any number of levels. For instance; time dimension can have 2 levels and the location dimension can have 1 level. However; in such a case, the number of different complexity level structures would be extreme and we would need to create an absurdly high number of alternatives, which would make performing the rating experiment difficult. Therefore, for convenience, the charge levels for each dimension is limited to either one or two.

The third attribute – number of exemptions and discounts – is given four levels [0,1,2,3]. 0 means that there is only 1 exemption / discount. For each level, the number is incremented. 3 means that there are 4 exemptions / discounts. Based on observations in Appendix I, the number of exemptions / discounts varied between 2 and 4; however in addition 1 was added to those in order to be able to create a level 11 complexity. (Given that the number of dimensions are either 5 or 6, each dimension has either 1 or 2 levels and number of dimensions / exemptions vary between 2 and 4; it would not be able to create a level 11 complexity. In order to overcome this, 1 was added as an option for the number of exemptions / discounts.) The attributes and the levels of the rating experiment are summarized below. (The levels in the rating experiment and the levels of dimensions are two separate things and not to be confused with each other.)

Table 3: Description of Attributes and Their Levels in the Rating Experiment

Attribute	Levels of the Attribute	Explanation
Number of Dimensions	[0, 1]	0: There are 5 dimensions. 1: There are 6 dimensions.
Number of Charge Levels	[0, 1]	0: Each dimension has 1 level. 1: Each dimension has 2 levels.

Number of Exemptions / Discounts	[0, 1, 2, 3]	0: There are 1 exemptions / discounts in total. 1: There are 2 exemptions / discounts in total. 2: There are 3 exemptions / discounts in total. 3: There are 4 exemptions / discounts in total.

Based on the description given in Table 3, and the description of complexity levels in Chapter 3.2., alternatives with complexity levels ranging from 6 to 16 can be generated in the rating experiment. Ngene software is used to create an orthogonal sequential design, assuming that there are no correlations between attributes. A sequential design is used, because the all alternatives have the same generic attributes.

The rating is done on a scale of 0 to 5. The participants of the experiment were asked to rate the given alternative; 0 being not acceptable and 5 being fully acceptable. The scale is chosen as such, because the conversion to percentages would be easier; in addition the scale would correspond to the values of the public acceptability attribute in the stated choice experiment in Chapter 7.

In the rating experiment, there are 2 attributes with 2 levels and 1 attribute with 4 levels. Use of Basic Plans, which are published orthogonal fractional factorial designs, suggest that we need 16 profiles (alternatives). One of the possible constructions is given below. Actual construction is done through the Ngene software.

Table 4: A Possible Construction for the Rating Experiment

Attributes / Levels			**Explanation**	**Complexity Level**
0	0	0	There are 5 dimensions, each dimension has 1 level, there are 1 exemptions / discounts in total.	6
0	1	0	There are 5 dimensions, each dimension has 2 levels, there are 1 exemptions / discounts in total.	11
1	0	0	There are 6 dimensions, each dimension has 1 level, there are 1 exemptions / discounts in total.	7
1	1	0	There are 6 dimensions, each dimension has 2 levels, there are 1 exemptions / discounts in total.	13
0	0	1	There are 5 dimensions, each dimension has 1 level, there are 2 exemptions / discounts in total.	7
0	1	1	There are 5 dimensions, each dimension has 2 level, there are 2 exemptions / discounts in total.	12
1	0	1	There are 6 dimensions, each dimension has 1 level, there are 2 exemptions / discounts in total.	8
1	1	1	There are 6 dimensions, each dimension has 2 levels, there are 2 exemptions / discounts in total.	14
0	0	2	There are 5 dimensions, each dimension has 1 level, there are 3 exemptions / discounts in total.	8
0	1	2	There are 5 dimensions, each dimension has 2 levels, there are 3 exemptions / discounts in total.	13
1	0	2	There are 6 dimensions, each dimension has 1 level, there are 3 exemptions / discounts in total.	9

1	1	2	There are 6 dimensions, each dimension has 2 levels, there are 3 exemptions / discounts in total.	15
0	0	3	There are 5 dimensions, each dimension has 1 level, there are 4 exemptions / discounts in total.	9
0	1	3	There are 5 dimensions, each dimension has 2 levels, there are 4 exemptions / discounts in total.	14
1	0	3	There are 6 dimensions, each dimension has 1 level, there are 4 exemptions / discounts in total.	10
1	1	3	There are 6 dimensions, each dimension has 2 levels, there are 4 exemptions / discounts in total.	16
First column: attribute ‘number of dimensions’, second column: attribute ‘number of charge levels’, third column: attribute ‘number of exemption / discounts’.				

Aside from rating the alternatives, participants were asked 7 other questions. The answers to these questions will later be used in the sensitivity analysis in Chapter9. The first three questions are derived from the literature review. Social norms, personal outcome expectations and perceived effectiveness are seen as the most important factors affecting acceptability.

The first question is about the social norms. The participants are asked how much they think the public reputation of congestion charges affected their decision making. Three choices are given: a) not at all, b) somewhat affected, c) considerably affected.

The second question is about personal outcome expectations. The participants are asked how beneficial would the congestion charging be for them individually. Three choices are given: a) not beneficial, b) somewhat beneficial, c) very beneficial.

The third question is about perceived effectiveness. The participants are asked what effect would the charging plan have on reducing the congestion according to them. Three choices are given: a) no effect at all, b) somewhat effective, c) very effective.

The fourth question is about whether the participant is a car driver or not. Two choices are given: a) car driver, b) not a car driver.

The fifth question is about the participants’ age. Five choices are given: a) 18-25, b) 26-35, c) 36-50, d) 51-60, e) 60+.

The sixth question is about the participants’ education level. Three choices are given: a) High school graduate, b) Bachelor graduate, c) Master graduate and above.

The seventh question is about the sex of the participants. Two choices are given: a) Male, b) Female.

The survey is delivered online and also manually at the campus of TU Delft and at the Student Hotel in Den Haag.

For the sake of reducing the effect of costs on public acceptability, the costs are not specifically mentioned in the text. Their variance (whether the cost is fixed or not) according to time and other factors are explained without providing numbers.

The rating experiment is performed simultaneously with the stated choice experiment in Chapter7. The respondents receive both surveys.

6.2. Drawbacks

The respondents were expected to rate each alternative independently. However, given a set of alternatives, some respondents may rate the alternatives in respect to other alternatives. This problem can cause respondents who oppose congestion charges to give ratings above zero. Therefore, the ratings we get might be higher than the actual ratings.

6.3. Pilot Rating Experiment

6.3.1. Aim of the Pilot Research

The aim of the pilot research was to see how the participants react to the rating experiment. If there are any issues with the wording of the survey and construction of the experiment, those would reveal themselves and be fixed for the main experiment. Another purpose of the pilot experiment was to see the range of the public acceptability level. This is necessary, because in the stated choice experiment public acceptability is used as an attribute which has three levels: 40%, 60%, 80%. The results of the pilot experiment, would show if there is a tendency of public acceptability to go above 80% or below 40%. If there is such a tendency, the levels of public acceptability in the stated choice experiment would be adjusted accordingly.

6.3.2. Design of the Rating Experiment: Ngene Syntax

The Ngene syntax of for the experiment is given below.

```
? orthogonal design for public acceptability
Design
; alts = alt1,base
; orth = seq
; rows = 16
; block = 2
; model:
U(alt1) = b1*A[0,1,2,3] + b2*B[0,1] + b3*C[0,1]
$
```

The total 16 alternatives of the rating experiment are divided into 2 blocks. One participant is going to rate only 8 different congestion charge implementations. The design that Ngene provided is given below in Table 16.

Table 5: Design of The Rating Experiment

Choice situation	alt1.a	alt1.b	alt1.c	Block	Complexity Level
4	3	0	1	1	14
5	1	1	0	1	8
8	2	1	1	1	15
9	3	1	1	1	16

11	2	0	0	1	8
13	1	0	1	1	12
14	0	1	0	1	7
16	0	0	0	1	6
1	0	0	1	2	11
2	1	1	1	2	14
3	3	1	0	2	10
6	2	0	1	2	13
7	0	1	1	2	13
10	2	1	0	2	9
12	1	0	0	2	7
15	3	0	0	2	9
alt1.a: levels of attribute: 'number of exemptions / discounts' alt1.b: levels of attribute: 'number of dimensions' alt1.c: levels of attribute: 'number of charge levels'. See Table 14 for the explanation of each level					

6.3.3. Text of Survey

The text of the pilot survey is given in Appendix II. Note that the survey was divided into 2 blocks: Block 1 and Block 2; however the pilot experiment was performed by using only Block 2. Therefore only the text of Block 2 is provided in Appendix II, because Block 1 is redundant. The reason for using only Block 2 is the following: The rating experiment and the stated choice experiment in Chapter 7 are performed together in the survey. The pilot stated choice experiment was divided into 2 blocks just as the rating experiment. Block 1 of both experiments were merged together and so as Block 2. In Block 1, within the stated choice experiment, there was too much dominance in choice situations, meaning that the choice of any logical decision maker was obvious and without any trade-off. For this reason, Block 1 was disregarded and the pilot experiment was carried on using only Block 2. The problem of dominance was later solved and there weren't any such issues in the main experiment.

6.3.4. Implementation

The survey was implemented both online (using google forms) and by hand amongst friends. There were 15 respondents in total. The demographics of the respondents are given below.

Table 6: Demographics of the Pilot Survey

Sex	
Male	73%
Female	27%
Age	
18-25	73%
26-35	20%
36-50	0%
51-60	77%
60+	0%

Education	
High school degree	0%
Bachelor's degree	73%
Master's degree or above	27%
Driver	
Yes	20%
No	80%
Reputation of Congestion Charges Affecting Their Decision	
Not at all	33%
Somewhat affected	47%
Considerably affected	20%
Individual Benefits from a Future Congestion Charging Implementation	
Not beneficial	20%
Somewhat beneficial	60%
Very beneficial	20%
Anticipated Effect of A Future Congestion Charging Implementation	
Not effective at all	7%
Somewhat effective	60%
Very effective	33%
N = 15	

The demographics show that there was a young male majority. The education level was dominated by bachelor's degree and a vast majority of the respondents were non-drivers. Answers to questions regarding reputation, individual benefits and anticipated effects were dominated by the 'somewhat' option.

6.3.5. Results: Regression Analysis

In the rating experiment, a scale of 0 to 5 was used. The rating represents the acceptability of a certain charging plan and since we measure acceptability in percentages, that scale has been converted to a 0 to 100 scale for convenience. In the rating experiment, some complexity levels occur more frequently than others, because some complexity levels can be reached by different formations. For instance, 5 dimensions, 2 levels within each dimension and 3 exemptions would result in a complexity level of 13; whereas 6 dimensions, 2 levels within each dimension and 1 exemption would also result in a complexity level of 13. This causes some complexity levels to be observed more than others. In order to prevent any biases in the regression analysis due to higher observances of some complexity levels, a weighted regression analysis is performed. Each complexity level was given a calculated weight which would balance the observational differences of complexity levels. Those weights are given in the table below. Sum of weights is equal to 1.

Table 7: Weights of Complexity Levels in the Pilot Experiment

Complexity Level	Number of Observations	Weight

7	15	0.2
9	30	0.1
10	15	0.2
11	15	0.2
13	30	0.1
14	15	0.2

Significance level was set to 0.05. The regression analysis gives a p-value less than 0.05, which means that there is a significant relationship between acceptability (A) and the complexity level (CL). The relationship is linear in nature and the regression equation is given below.

$$A = -4.0 + 5.44\ CL$$

The regression equation results in the following line plot.

Figure 3: Line Plot for Acceptability vs. Level of Complexity – Pilot Experiment

The regression analysis shows that as the level of complexity increases, acceptability also increases. The acceptability level slightly goes over 80 and drops below 40, but it only occurs at either very high or very low complexity levels; therefore there is no need to change the acceptability levels (40%, 60%, 80%) in the main survey. The detailed results from Minitab are given in Appendix III.

6.4. Main Rating Experiment

6.4.1. Changes Made to the Ngene Syntax and the Final Text

There was no change made to the Ngene syntax. The main rating experiment was divided into same 2 blocks just as it was in the pilot. On the other hand, the final text of the rating experiment was subject to some changes. Each charging plan was rephrased in a more clear way, so that the respondents would see the number of dimensions, number of charge levels and number of discounts and exemptions at first glance. In addition, to make it easier to separate between charging plans with different levels of ‘number of charge levels’, charging plans were colored. As mentioned previously, there are two levels for the attribute ‘number of charge levels’ : each dimension has one level or each dimension has two levels. These are referred as ‘Variation 1’ and ‘Variation 2’ in the survey. Each charging plan with variation 1 was colored green and variation 2 was colored blue. The text of the main rating experiment is given in Appendix II.

6.4.2. Implementation

The survey was implemented both online and by hand. The link to the survey was e-mailed to academics who work at TU Delft. The link was also sent to friends, and published on my social network accounts (Facebook and Twitter). The survey was performed by hand at the campus of TU Delft and at the Student Hotel in Den Haag where I currently live. Performing the survey by hand was useful in balancing the number of respondents in each block of the survey. When one of the blocks was running behind the other one, I gave priority to that block when I was manually handing out the survey. In addition, there was a male dominance among respondents, and the gap was quite large between male-female respondents at the beginning, so I tried to choose mainly female respondents when I was handing out the survey. There were 92 respondents in total. Block 1 had 44 respondents and Block 2 had 48 respondents. The demographics of the survey are given in the table below.

Table 8: Demographics of the Main Survey

Sex	
Male	59%
Female	41%
Age	
18-25	40%
26-35	29%
36-50	18%
51-60	13%
60+	0%
Education	
High school degree	0%
Bachelor's degree	37%
Master's degree or above	63%
Driver	
Yes	22%
No	78%
Reputation of Congestion Charges Affecting Their Decision	
Not at all	26%
Somewhat affected	45%
Considerably affected	29%
Individual Benefits from a Future Congestion Charging Implementation	
Not beneficial	21%

Somewhat beneficial	60%
Very beneficial	19%
Anticipated Effect of A Future Congestion Charging Implementation	
Not effective at all	12%
Somewhat effective	70%
Very effective	18%
N = 92	

Demographics show that there is a male dominance among respondents. Age group 18-25 make up for around 40% of the respondents and dominate the age category. The respondents are all highly educated, there is not a single respondent without a college level education. The vast majority of around 80% of respondents don't use a car as their primary mode of transport inside the city. The answers to questions regarding the reputation, individual benefits and anticipated effects of a congestion charging plan were dominated by the 'somewhat' response. The demographics of the respondents and how they affect the results are taken into account in detail while performing the sensitivity analysis in Chapter 9.

6.4.3. Results: Regression Analysis

The raw data includes 736 (92*8) data points. A representation of the raw data is given below. Higher concentration of color indicates higher number of observations.

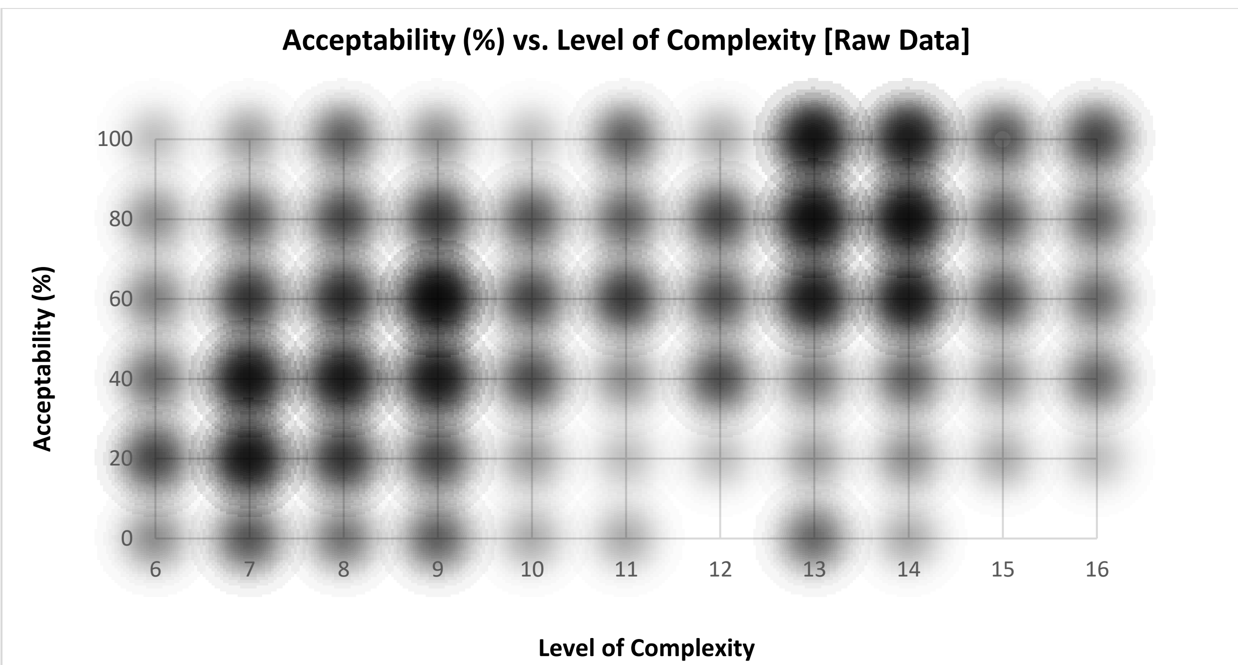

Figure 4: Raw Data for Acceptability vs. Level of Complexity – Main Experiment

In order to understand the raw data more clearly, average acceptability level per level of complexity is expressed in the following graph.

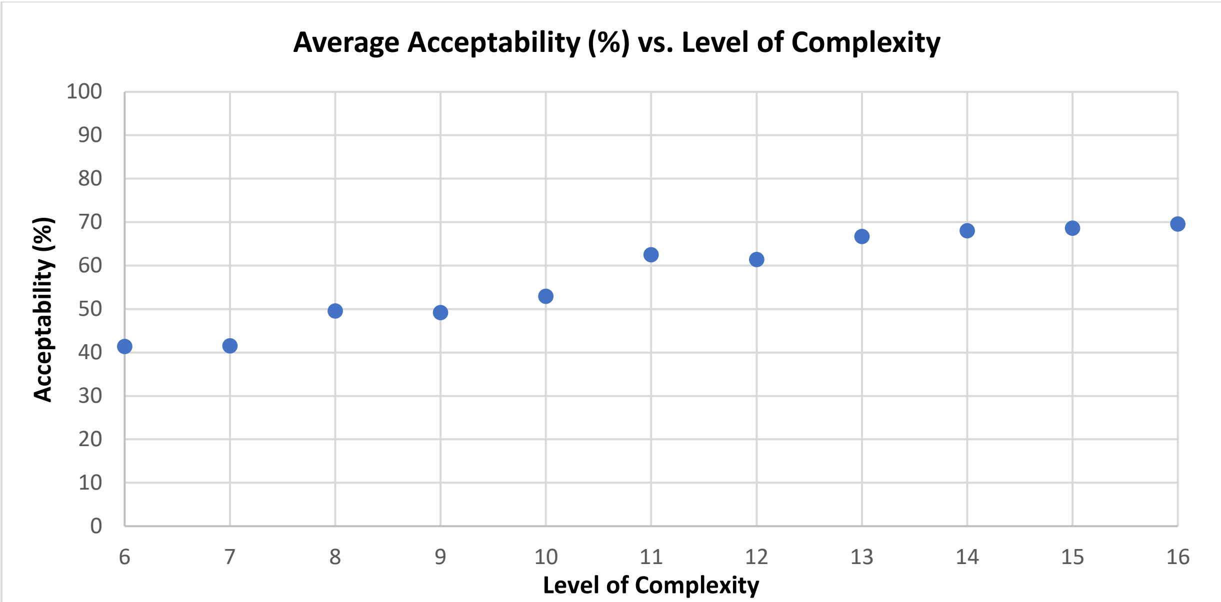

Figure 5: Average Acceptability vs. Level of Complexity

A weighted regression analysis was performed similarly to the regression analysis of the pilot experiment. The weights are given in the table below.

Table 9: Weights of Complexity Levels in the Main Experiment

Complexity Level	Number of Observations	Weight
6	44	0.1219
7	92	0.0583
8	88	0.0609
9	96	0.0558
10	48	0.1117
11	48	0.1117
12	44	0.1219
13	96	0.0558
14	92	0.0583
15	44	0.1219
16	44	0.1219

Significance level was set to 0.05. The regression analysis gives a p-value less than 0.05, which means that there is a significant relationship between acceptability (A) and the complexity level (CL). The detailed results from Minitab are given in Appendix III. The relation is linear in nature, as determined by the software. The regression equation is:

$$A = 22.56 + 3.166\ CL$$

The regression equation results in the following line plot.

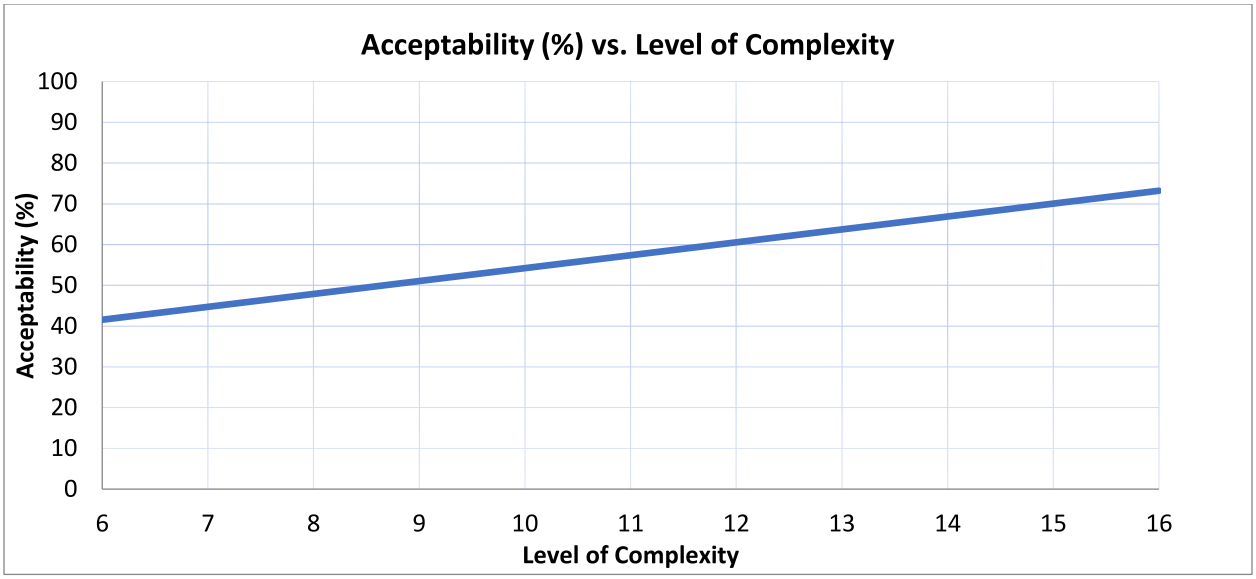

Figure 6: Line Plot for Acceptability vs. Level of Complexity - Main Experiment

The regression analysis shows that as the level of complexity increases, acceptability also increases. Acceptability levels are within the range of 40 to 80. Compared to the pilot experiment, the results are quite similar, there is no significant changes and the direction of the relationship is same in both cases.

6.5. Issue of Complexities with Same Level but with Different Structure

It was previously mentioned that some complexity levels can be achieved by different structures. A complexity level is structured by 3 attributes: number of dimensions, number of charge levels within those dimensions and the number of exemptions / discounts. For instance complexity level 13 can be achieved by 6 dimensions, 2 charge levels within each and 1 exemption / discount; it can also be achieved by 5 dimensions, 2 charge levels within each and 3 exemptions / discounts. In order to find how each of those 3 attributes affect the acceptability level, a multiple regression analysis was performed. The multiple regression concludes that only two of the attributes are statistically significant: number of charge levels within dimensions and number of exemptions / discounts. See the figure below. The analysis shows that number of charge levels has a far more impact than number of exemptions / discounts.

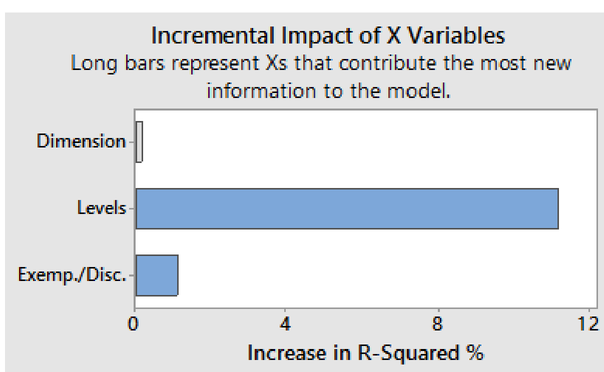

Figure 7: Impact of the Individual Attributes of Complexity Levels on Acceptability

Multiple regression analysis gives the following regression equation for acceptability (A):

$$A = 20.48 + 19.68 * Number\ of\ Charge\ Levels + 2.659 * Number\ of\ Exemptions\ /\ Discounts$$

This results suggests the following: If there are two complexities with the same level but different structures, then primarily the complexity with higher charge levels and to a lesser degree with higher number of exemptions / discounts provides more acceptability.

6.6. Conclusion

The second sub-question and the aim of this chapter was to determine the relationship between public acceptability and the complexity level of a congestion charging implementation. The answer to that question is that the relationship between the two is positive and linear and the relationship is statistically significant. The robustness of the acceptability function will be tested in Chapter 9: Sensitivity Analysis.

7. Tradeoff Between Effectiveness and Public Acceptability

In this chapter, a stated choice experiment is performed in order to answer to the third sub question: **What is the trade-off between the effectiveness of congestion charging and the public acceptability level?**

7.1. Research Design Choices

For this experiment, the following attributes are set: (1) public acceptability and (2) effectiveness.

The attribute – public acceptability – has three levels [40, 60, 80]. In the rating experiment in Chapter 6, their values refer to 2, 3 and 4 on the rating scale respectively.

The attribute – effectiveness – has three levels [10, 15, 20]. These values are chosen based on the case studies performed in Appendix I. The attributes and the levels of the stated choice experiment are summarized below.

Table 10: Description of Attributes and Their Levels in the Stated Choice Experiment

Attributes	Levels of Attributes	Explanation
Public Acceptability	[40, 60, 80]	40: 40% public acceptability 60: 60% public acceptability 80: 80% public acceptability
Effectiveness	[10, 15, 20]	10: 10% effectiveness (reduction in congestion) 15: 15% effectiveness 20: 20% effectiveness

In the this stated choice experiment, there are 2 attributes with 3 levels. Use of Basic Plans, which are published orthogonal fractional factorial designs, suggest that we need 9 profiles (alternatives). One of the possible constructions is given below. Actual construction is done through the Ngene software.

Table 11: Alternatives of the Stated Choice Experiment

Attributes / Levels		Explanation
40	10	Congestion charging plan has 40% public acceptability, it is expected to have an effectiveness of 10% reduction in congestion.
40	15	Congestion charging plan has 40% public acceptability, it is expected to have an effectiveness of 15% reduction in congestion.
40	20	Congestion charging plan has 40% public acceptability, it is expected to have an effectiveness of 20% reduction in congestion.
60	10	Congestion charging plan has 60% public acceptability, it is expected to have an effectiveness of 10% reduction in congestion.
60	15	Congestion charging plan has 60% public acceptability, it is expected to have an effectiveness of 15% reduction in congestion.
60	20	Congestion charging plan has 60% public acceptability, it is expected to have an effectiveness of 20% reduction in congestion.

80	10	Congestion charging plan has 80% public acceptability, it is expected to have an effectiveness of 10% reduction in congestion.
80	15	Congestion charging plan has 80% public acceptability, it is expected to have an effectiveness of 15% reduction in congestion.
80	20	Congestion charging plan has 80% public acceptability, it is expected to have an effectiveness of 20% reduction in congestion.
First column: attribute ‘public acceptability’, second column: attribute ‘effectiveness’.		

The seven questions that were asked in the rating experiment to participants were also be asked in the stated choice experiment to identify the demographics of the respondents. The two parts of the survey were actually handed to the same respondent, so in reality, the questions were only asked once.

To construct the experiment, a d-efficient design with fold-over is used. A d-efficient design takes into account both variances and covariances and is based on the determinant of the AVC (asymptotic variance-covariance) matrix. An efficient design is chosen over an orthogonal design, because they result in smaller standard errors. A fold-over design ensures that the main context effects do not correlate with their two-way interactions to avoid any bias.

In order to use an efficient design, priors are needed. Priors are best guesses on parameter values that are used to calculate the utility of each alternative. Prior values are determined by the pilot experiment. The aimed sample size was equal to or above 15 respondents.

The survey was delivered online and also manually at the campus of TU Delft, and at the Student Hotel in Den Haag.

In the survey, the respondents were asked to put themselves in the shoes of policy makers, because the utility is aimed to be observed from the perspective of policy makers, and making a trade off between effectiveness and acceptability is not something that the public would usually do.

7.2. Drawbacks

Asking respondents to put themselves in the shoes of policy makers is a drawback, because the responses of actual policy makers might be different than the responses we get from the stated choice experiment. This can cause differences in the results.

7.3. Pilot Stated Choice Experiment

7.3.1. Aim of the Pilot Research

The main purpose of the pilot experiment was to estimate the priors for the main stated choice experiment. Similarly to the rating experiment, it was also aimed to see how the participants react to the stated choice experiment and if there were any issues with the wording of the survey and construction of the experiment.

7.3.2. Design of the Stated Choice Experiment: Ngene Syntax

The Ngene syntax of for the experiment is given below.

```
? d-efficient design with foldover
Design
; alts = alt1,alt2
; rows = 9
;eff = (mnl,d)
;foldover
;block=2
; model:
U(alt1) = b1*A[40,60,80] + b2*B[10,15,20]/
U(alt2) = b1*A+b2*B
$
```

In Chapter 6.3.3., it was explained that only Block 2 was used in the pilot experiment and Block 1 was disregarded. The reason for this is that there was too much dominance in choice situations. The reason behind this dominance is that the Ngene syntax for the pilot stated choice experiment did not include necessary coding to avoid dominance. In addition, choosing a fold-over design was a mistake, because there are only 9 choice sets in total which do not have any dominance and these 9 choice sets can all be represented in a single block; thus using a fold-over design and creating 2 blocks was not necessary. In Block 2 of the pilot stated choice experiment, among 9 choice sets, only 6 were free of dominance. When implementing the survey, I removed the dominant choice sets from the survey and the survey was performed with 6 choice sets. The design for the pilot stated choice experiment is given below. Note that entire Block 1 and the dominant choice sets in Block 2 are cropped out.

Table 12: Design of the Pilot Stated Choice Experiment

Choice Situation	alt1.a	alt1.b	alt2.a	alt2.b	Block
2	60	20	80	15	2
4	40	15	80	10	2
5	60	10	40	15	2
11	60	10	40	20	2
13	80	15	40	20	2
18	40	20	80	10	2
alt1.a: levels of attribute: ‘public acceptability alt1.b: levels of attribute: ‘effectiveness’					

7.3.3. Text of Survey

The text of the survey is given in Appendix II. The text comes after the questions regarding the rating experiment.

7.3.4. Implementation

The pilot stated choice experiment was implemented simultaneously with the pilot rating experiment. Therefore, the method of implementation, number of respondents and the demographics are the same as the pilot rating experiment. In order to avoid repetition, please see Chapter 6.3.4. for those details.

7.3.5. Results: Priors and Preliminary MNL Model

The data collected through the pilot stated choice experiment was analyzed in Biogeme as an MNL (logit) model. The mod file for the analysis is given below.

```
[ModelDescription]

[Choice]
Choice

[Beta]
B_EF    0       -10000  10000   0
B_PA    0       -10000  10000   0

[Utilities]
1       Alt1    av1     B_PA * PA1 + B_EF * EF1
2       Alt2    av2     B_PA * PA2 + B_EF * EF2

[Expressions]
av1 = 1
av2 = 2

[Model]
$MNL
```

Utility of a congestion charging plan depends on the public acceptability (A) for that plan and the anticipated effectiveness (E) of that plan.

$$U = \beta_{Effectiveness} * E + \beta_{Public\ Acceptability} * A$$

Based on this utility function, parameters for public acceptability and the effectiveness were estimated. A scale of 0 to 100 was used for effectiveness. Biogeme gives the following estimates for the parameters:

$$\beta_{Effectiveness} = 0.0773$$
$$\beta_{Public\ Acceptability} = 0.0437$$

The detailed results from Biogeme are provided in Appendix III. The results show that effectiveness parameter is significantly higher than the acceptability parameter. A single unit increase in effectiveness raises the utility more than a single unit increase in acceptability.

The estimated parameters for $\beta_{Effectiveness}$ and $\beta_{Public\ Acceptability}$ are going to be used as priors when designing the main stated choice experiment.

The S estimate was 31.47, so the minimum number of respondents should be 32 in the main stated choice experiment, in order to significantly estimate the parameters.

7.4. Main Stated Choice Experiment

7.4.1. Changes Made to the Ngene Syntax and the Final Text

Ngene syntax was changed in order to include necessary coding to avoid dominance. Syntax was also changed to remove the fold-over design completely, as in Chapter 7.3.2. it was explained that a fold-over design was actually not necessary. In addition, priors found from the pilot experiment were added to the syntax.

The new Ngene syntax is given below.

```
Design
; alts = alt1*,alt2*
; rows = 9
;eff = (mnl,d)
; model:
U(alt1) = b1[0.0437]*A[40,60,80] + b2[0.0773]*B[10,15,20]/
U(alt2) = b1*A+b2*B
$
```

The resulting design is given below.

Table 13: Design of the Main Stated Choice Experiment

Choice Situation	alt1.a	alt1.b	alt2.a	alt2.b
1	80	10	40	15
2	80	15	40	20
3	60	15	80	10
4	40	20	80	10
5	40	20	60	15
6	80	10	60	20
7	40	15	60	10
8	60	10	40	20
9	60	20	80	15
alt1.a: levels of attribute: 'public acceptability alt1.b: levels of attribute: 'effectiveness'				

The text of the survey is given in Appendix II. Note that there are two blocks: Block 1 and Block 2; however the stated choice experiment is exactly the same in both blocks, the only difference is in the rating experiment.

7.4.2. Implementation

The stated choice experiment was implemented simultaneously with the rating experiment. Therefore, the method of implementation, number of respondents and the demographics are the same as the rating experiment. In order to avoid repetition, please see Chapter 6.4.2. for those details.

7.4.3. Results: MNL Model

The data collected through the main stated choice experiment was analyzed in Biogeme as an MNL (logit) model. The mod file used for the analysis in Biogeme is exactly the same as the one used in the pilot stated choice experiment. Biogeme gives the following estimates for the parameters:

$$\beta_{Effectiveness} = 0.105$$
$$\beta_{Public\ Acceptability} = 0.0338$$

Compared to the results of the pilot experiment, the effectiveness parameter is slightly higher and the acceptability parameter is slightly lower. There are no significant differences between the two results. Effectiveness parameter is still higher than the acceptability parameter. The detailed results from Biogeme are provided in Appendix III. P-values of both parameters are below zero, thus both parameters are statistically significant.

7.5. Conclusion

The third sub-question and the aim of this chapter was to determine the trade-off between the public acceptability and the anticipated effectiveness level of a congestion charging implementation. The answer to that question is that the ratio between effectiveness parameter and the acceptability parameter is $\frac{\beta_{Effectiveness}}{\beta_{Public\ Acceptability}} = 3.11$; therefore one unit of effectiveness level can be traded off with 3.11 units of acceptability level. (Note that effectiveness and acceptability levels are percentages, but for convenience they are placed on a scale of 0 to 100). The results show that effectiveness parameter is higher than the acceptability parameter which means that a single unit increase in effectiveness is more important for utility than a single unit increase in acceptability. However, one should keep in mind that in the stated choice experiment and also in actual implementations, effectiveness has a range between 10 to 20, whereas acceptability has a range between 40 to 80.

8. Relationship Between Utility and Congestion Charging Complexity

The utility function based on effectiveness (E) and public acceptability (A) is given below.

$$U = \beta_{Effectiveness} * E + \beta_{Public\ Acceptability} * A$$

Parameters $\beta_{Effectiveness}$ and $\beta_{Public\ Acceptability}$ come from the stated choice experiment as the findings of the third sub question. The relationship between effectiveness and complexity was examined in Chapter 5. The regression equations found in Chapter 5 will replace the E variable in the utility function. The relationship between public acceptability and complexity was examined in Chapter 6. The regression equation found in Chapter 6 will replace the A variable in the utility function. Utility function will be rewritten as a function of complexity. Using this function, the relationship between complexity level and utility is going to be determined.

As mentioned in Chapter 5, there are two different effectiveness functions and both of them are going to be used; because the relationship between effectiveness and complexity level is not conclusive. In order to reach a conclusive result for the relationship between complexity and utility, utility needs to observed in both cases when the effectiveness function is positive and when it is negative.

8.1. Utility vs. Complexity when the Effectiveness Function is Positive

Regression equation that gives the relationship between effectiveness (E) and complexity level (CL):

$$E = 1.100 + 1.046\ CL$$

Regression equation that gives the relationship between public acceptability (A) and complexity level (CL):

$$A = 22.56 + 3.166\ CL$$

Parameters for effectiveness and public acceptability are:

$$\beta_{Effectiveness} = 0.105, \qquad \beta_{Public\ Acceptability} = 0.0338$$

The utility function transforms into:

$$U = \beta_{Effectiveness} * E + \beta_{Public\ Acceptability} * A$$

$$U = 0.105 * (1.100 + 1.046\ CL) + 0.0338 * (22.56 + 3.166\ CL)$$

$$U = 0.8780 + 0.2168\ CL$$

The utility function shows that there is a positive relationship between utility and the complexity level. The line plot for the utility function is given below.

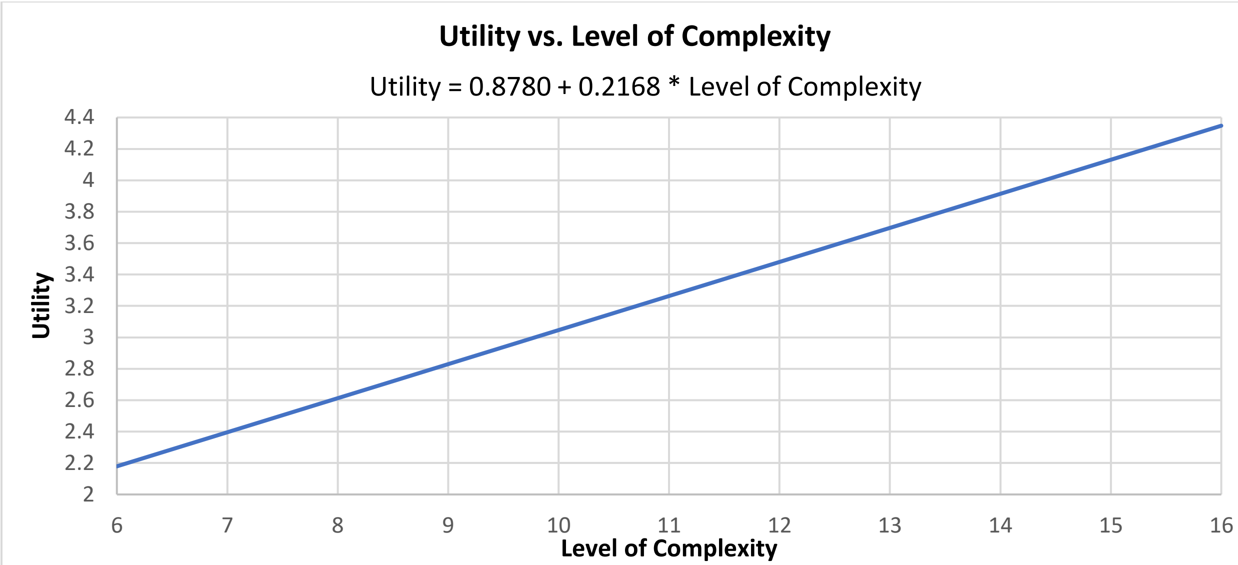

Figure 8: Line Plot for Utility vs. Level of Complexity when Effectiveness Function is Positive

8.2. Utility vs. Complexity when the Effectiveness Function is Negative

Regression equation that gives the relationship between effectiveness (E) and complexity level (CL):

$$E = 25.67 - 0.9185\ CL$$

Acceptability function and the estimated parameters remain the same. The utility function transforms into:

$$U = \beta_{Effectiveness} * E + \beta_{Public\ Acceptability} * A$$

$$U = 0.105 * (25.67 - 0.9185\ CL) + 0.0338 * (22.56 + 3.166\ CL)$$

$$U = 3.4579 + 0.0106\ CL$$

The utility function shows that there is a positive relationship between utility and the complexity level. The line plot for the utility function is given below.

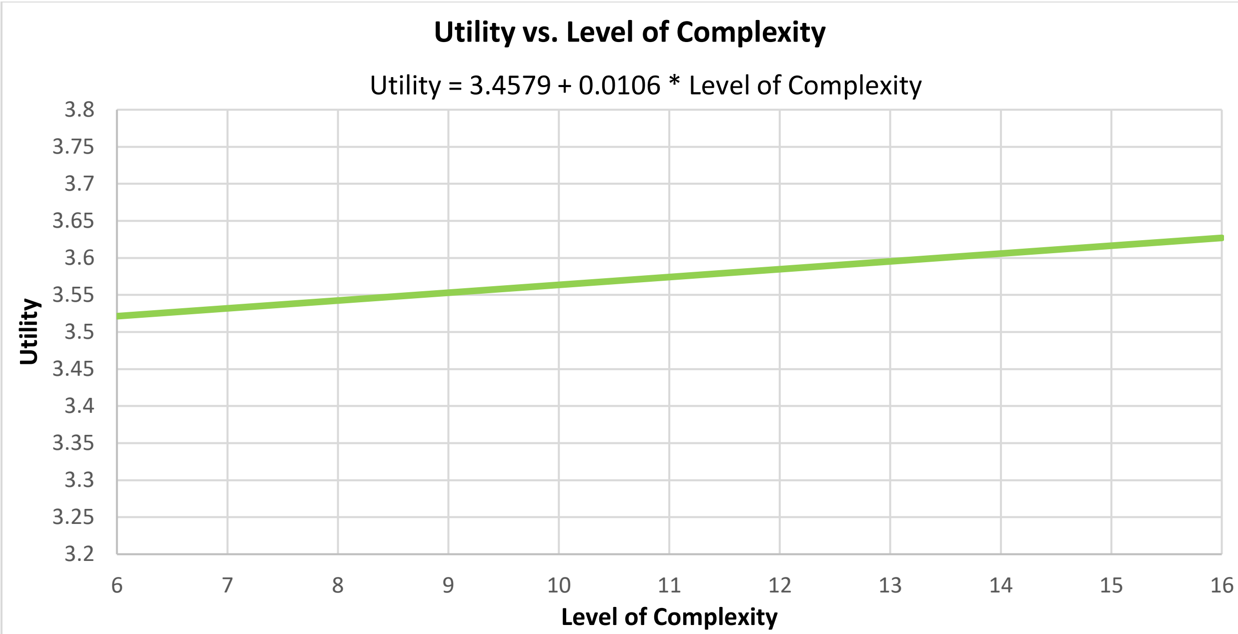

Figure 9: Line Plot for Utility vs. Level of Complexity when Effectiveness Function is Negative

8.3. Heterogeneity in Results

For the rating experiment, which led to the acceptability function, rho-square is 11.75%. For the stated choice experiment, which led to the parameter estimates, rho-square is 3.4%. Rho-squares are small for both models, which means that a large part of the variance in the data cannot be explained by those models and therefore there is a substantial level of unobserved heterogeneity in utility.

8.4. Conclusion

In both cases, when the effectiveness function is positive and negative, the utility function remains positive. This result can be interpreted in the following way: the acceptability function is steep enough and the acceptability parameter is strong enough that even a directional change (from positive to negative and vice versa) in the effectiveness function does not change the positive relationship between utility and complexity level.

When the effectiveness function is positive, utility function is steeper and the utility range is larger. On the other hand, when the effectiveness function is negative, utility function becomes more flat and the utility range becomes smaller.

As the answer to the main research question: this finding creates a strong case to conclude that there is a significant positive linear relationship between complexity and utility; utility increases as the level of complexity increases. The robustness of this result will be tested in Chapter 9: Sensitivity Analysis.

9. Sensitivity Analysis

9.1. Method

In the rating and stated choice experiments, respondents were asked to answer seven questions in addition to the choice questions. Those questions are used to build a demographic data for the experiments. The questions were about the social norms, personal outcome expectations, perceived effectiveness, whether or not they drive a car, their sex, age and educational levels. In this chapter, it will be investigated how the results of this research would change if only certain demographic groups were taken as reference. How would acceptability be affected if only the car drivers' responses were taken into account? How would the utility change if only respondents with high personal outcome expectations were taken into account? The sensitivity analysis will test the robustness of the findings in Chapter 8.

There are two separate sections for the sensitivity analysis:

- Sensitivity analysis for the acceptability function, in which all the response groups of those seven questions are analyzed. Recall that the acceptability is from **the perspective of public** (respondents of the survey).
- Sensitivity analysis for the utility function, in which only the response groups for the question of social norms are analyzed, for both when effectiveness function is positive and negative. It is assumed that it would not make sense to look at how parameters of the utility function would change based on other questions. Recall that the utility is from the **perspective of policy makers**; respondents are asked to put themselves in policy makers' shoes in the stated choice experiment. Analyzing the utility based on male/female policy makers or on policy makers with bachelor's degree or master's degree etc. would not be logical. Social norms, on the other hand, is about the reputation of congestion charges affecting respondents' decision making. Therefore, policy makers who are affected by that reputation and who are not can provide an insightful analysis.

9.2. Sensitivity Analysis for the Acceptability Function

The acceptability functions were re-estimated with weighted regression in Minitab according to the answers given in the rating experiment by a certain group.

9.2.1. Based on Social Norms

The surveys in Chapter 6 and 7 included a question regarding the social norms. The respondents were asked if the reputation of congestion charges affected their decision making. The following answers were given:

Table 14: Percentage Distribution of the Answers to the Social Norm Question

Reputation of Congestion Charges Affecting Their Decision (N = 92)	
Not at all	26%
Somewhat affected	45%
Considerably affected	29%

The re-estimated acceptability functions for each response group is given below.

Table 15: Re-estimated Acceptability Functions Based on Social Norms

Response Group	Re-estimated Acceptability Function
Not at all	A = 34.53 + 1.859 CL
Somewhat affected	A = 2.48 + 5.443 CL
Considerably affected	A = 40.92 + 0.933 CL

The line plots for these acceptability functions are given below.

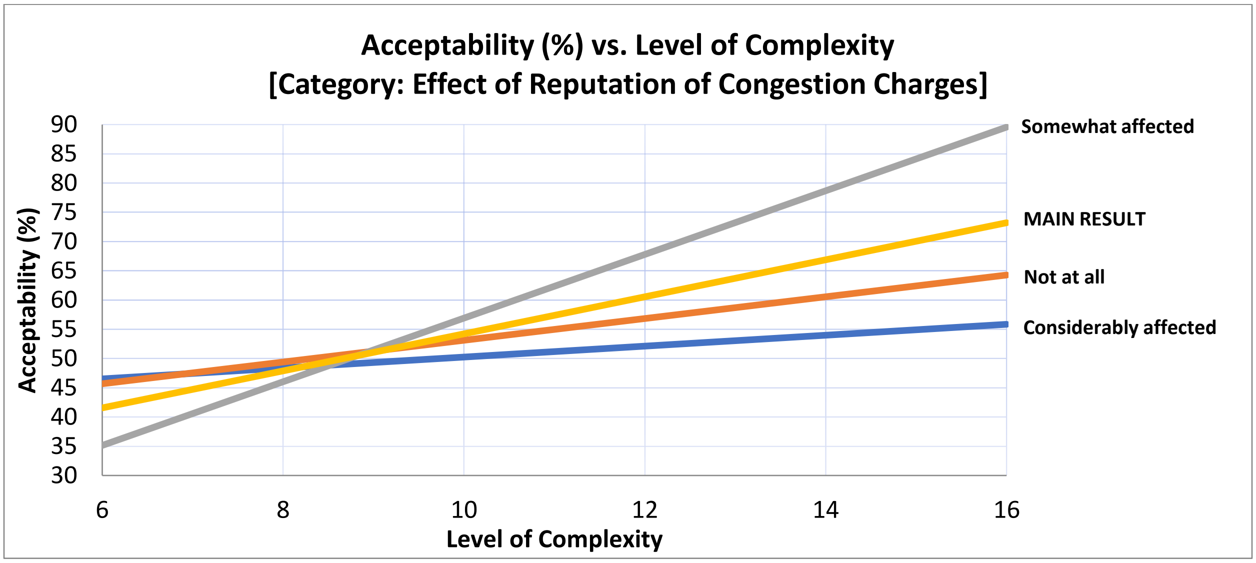

Figure 10: Line Plot for Acceptability vs. Level of Complexity Based on Social Norms

The line plot reveals that respondents who choose the 'somewhat affected' option has a steeper acceptability function than others. Their acceptability levels are lower at lower complexity levels, but they get significantly higher than other response groups once the complexity level increases.

Another finding from the line plot is that respondents who said that their decision making was considerably affected by the reputation of congestion charges have very low acceptability levels overall. Their acceptability levels range between 45 and 55 and are significantly below the main result. This finding suggests that the respondents' decision making was affected in a negative way. This can be interpreted in the way that people who were familiar with congestion charging implementations have lower acceptability levels compared to others. If the answers to this question were equally distributed among the three options, the main acceptability function would become less steep and consequently the acceptability range would become smaller.

9.2.2. Based on Personal Outcome Expectations

The surveys included a question regarding the personal outcome expectations of respondents. The respondents were asked if a future congestion charging plan would be individually beneficial for them. The following answers were given:

Table 16: Percentage Distribution of the Answers to the Personal Outcome Expectation Question

Individual Benefits from a Future Congestion Charging Implementation (N = 92)	
Not beneficial	21%
Somewhat beneficial	60%
Very beneficial	19%

The re-estimated acceptability functions for each response group is given below.

Table 17: Re-estimated Acceptability Functions Based on Personal Outcome Expectations

Response Group	Re-estimated Acceptability Function
Not beneficial	A = 30 + 1.656 CL
Somewhat beneficial	A = 25.27 + 3.027 CL
Very beneficial	A = -3.85 + 5.949 CL

The line plots for these acceptability functions are given below.

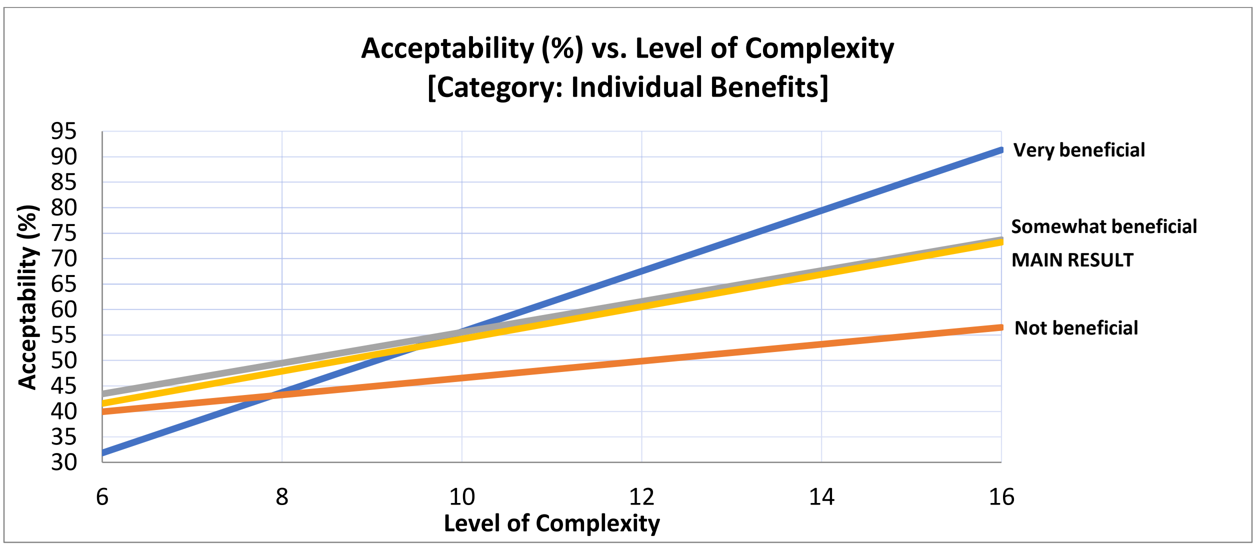

Figure 11: Line Plot for Acceptability vs. Level of Complexity Based on Personal Outcome Expectations

The line plot reveals that response group 'very beneficial' has a much steeper acceptability function compared to others, so as the level of complexity increases they tend to have higher acceptability levels than others. The response group ' somewhat beneficial' has almost the same acceptability function with the entire population. The response group 'not beneficial' has a less steeper acceptability function and tend to have lower acceptability levels compared to the rest of the population. These findings suggest that if the personal outcome expectation is high (very beneficial), the acceptability will be higher; and if the personal outcome expectation is low (not beneficial), the acceptability tends to be lower.

9.2.3. Based on Perceived Effectiveness

The surveys included a question regarding the perceived effectiveness of congestion charges amongst respondents. The respondents were asked what kind of an effect a future congestion charging plan would have according to them if implemented in their own city. The following answers were given:

Table 18: Percentage Distribution of the Answers to the Perceived Effectiveness Question

Anticipated Effect of A Future Congestion Charging Implementation (N = 92)	
Not effective at all	12%
Somewhat effective	70%
Very effective	18%

The re-estimated acceptability functions for each response group is given below.

Table 19: Re-estimated Acceptability Functions Based on Perceived Effectiveness

Response Group	Re-estimated Acceptability Function
Not effective at all	A = 47.72 + 0.748 CL
Somewhat effective	A = 17.57 + 3.7 CL
Very effective	A = 21.13 + 3.09 CL

The line plots for these acceptability functions are given below.

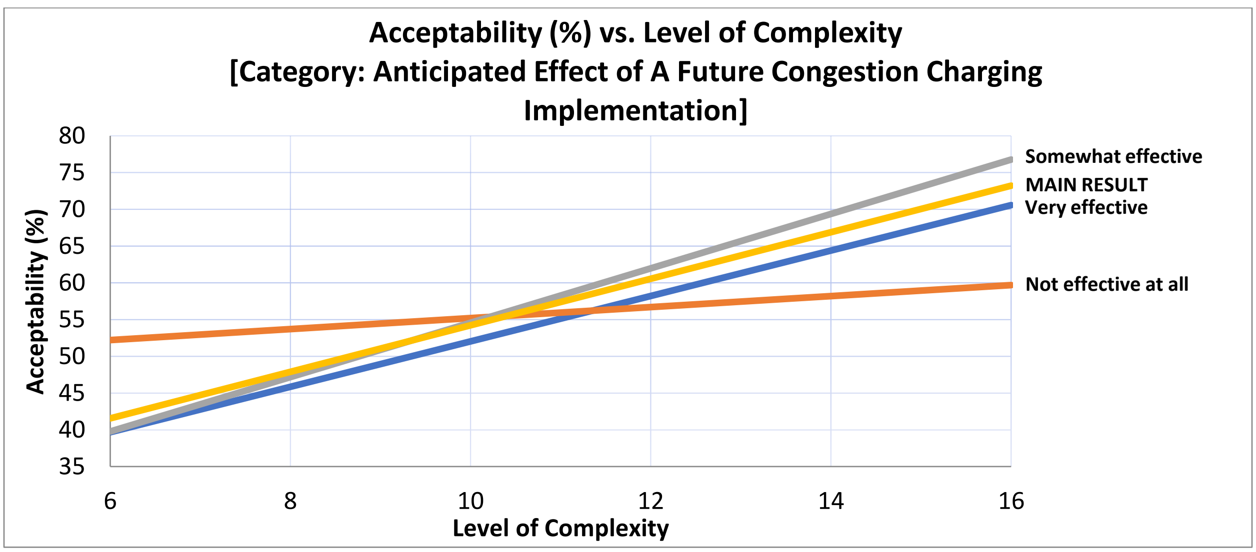

Figure 12: Line Plot for Acceptability vs. Level of Complexity Based on Perceived Effectiveness

An interesting finding in the line plot is that the response group 'not effective at all' has a very flat acceptability function and their acceptability level ranges between 50 to 60 which is much lower compared to the rest of the population. This can be interpreted in the way that people who think a congestion charging plan would not be effective at all in their city have lower acceptability levels as the complexity increases. The other two response groups have a similar acceptability functions and fall closely near the main result. If the answers to this question were equally distributed among the three options, the main acceptability function would become less steep and consequently the acceptability range would become smaller.

9.2.4. Based on Being a Driver or Non-Driver

In the survey, the respondents were asked whether they drive a car inside the city as their primary mode of transport or not. The following answers were given:

Table 20: Percentage Distribution of Answers to the Driver Question

Driver (N = 92)	
Yes	22%
No	78%

The re-estimated acceptability functions for each response group is given below.

Table 21: Re-estimated Acceptability Functions Based on the Driver Question

Response Group	Re-estimated Acceptability Function
Yes	A = 27.04 + 3.016 CL
No	A = 21.16 + 3.239 CL

The line plots for these acceptability functions are given below.

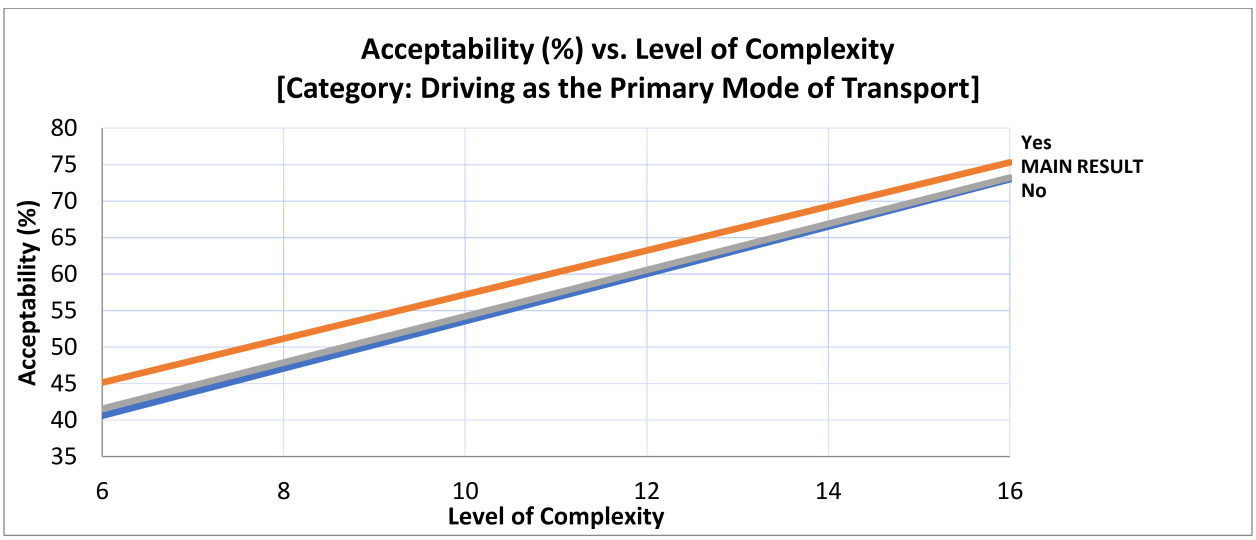

Figure 13: Line Plot for Acceptability vs. Level of Complexity Based on the Driver Question

Fürst and Dieplinger (2014), in their paper regarding the acceptability levels in Vienna, suggested that non-drivers could have higher acceptability levels; however according to the findings in this thesis research there are no drastic differences between the acceptability levels of drivers and non-drivers, it seems that drivers even have slightly higher acceptability levels. This can be interpreted in the following way: drivers who are first hand acquainted with the congestion might be more acceptive because they want the congestion to be reduced. If the answers to this question were equally distributed among the two options, the main acceptability function would move upwards in the y-axis, causing higher acceptability levels overall.

9.2.5. Based on Sex

In the survey, the respondents were asked to mark their sex. The following answers were given:

Table 22: Percentage Distribution of Answers to the Sex Question

Sex (N = 92)	
Male	59%
Female	41%

The re-estimated acceptability functions for each response group is given below.

Table 23: Re-estimated Acceptability Functions Based on Sex

Response Group	Re-estimated Acceptability Function
Male	A = 21.27 + 3.759 CL
Female	A = 14.83 + 3.132 CL

The line plots for these acceptability functions are given below.

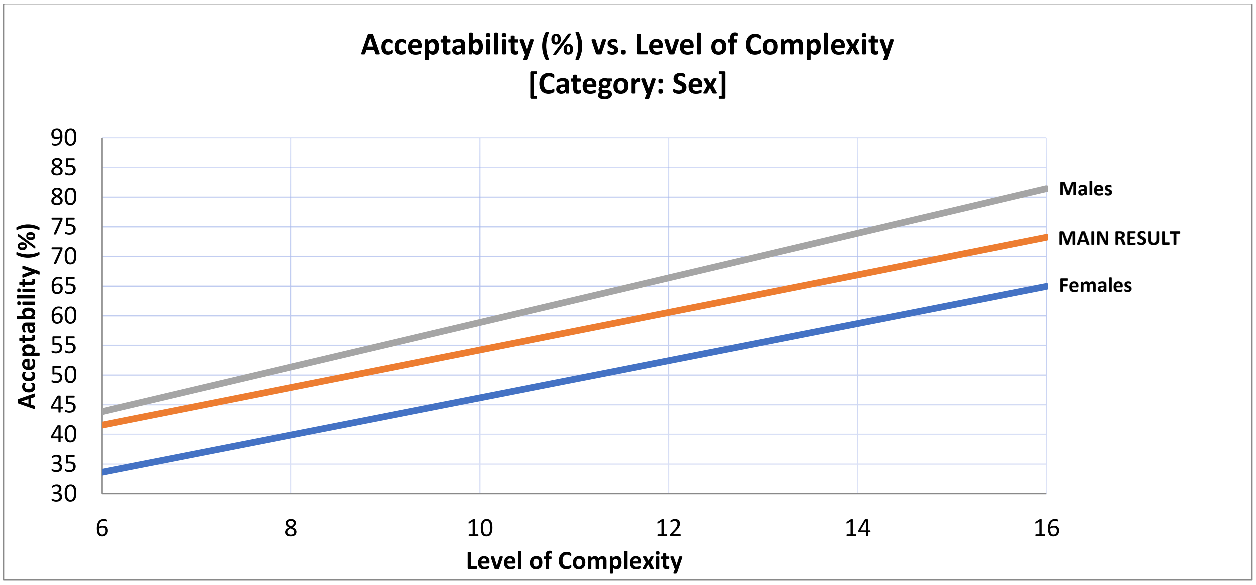

Figure 14: Line Plot for Acceptability vs. Level of Complexity Based on Sex

The line plots show that males have higher acceptability levels overall and females have lower acceptability levels overall compared to the main result. Males have a steeper acceptability function compared to females, meaning that their acceptability increases in a higher rate as the complexity level increases. Initially, I was expecting to have no significant differences between male and female respondents; however, the results show that there might be a difference worth investigating. More research is needed to test this finding. If males and females had equal ratios amongst respondents, the main acceptability function would become less steep and have lower acceptability levels overall.

9.2.6. Based on Age

In the survey, respondents were asked to mark their age group. The following answers were given:

Table 24: Percent Distribution of Answers to the Age Question

Age (N = 92)	
18-25	40%
26-35	29%
36-50	18%
51-60	13%
60+	0%

The re-estimated acceptability functions for each response group is given below.

Table 25: Re-estimated Acceptability Functions Based on Age

Response Group	Re-estimated Acceptability Function
18-25	A = 9.66 + 4.087 CL
26-35	A = 19.04 + 3.146 CL
36-50	A = 28.17 + 2.728 CL
51-60	A = 25.02 + 3.773 CL

The line plots for these acceptability functions are given below.

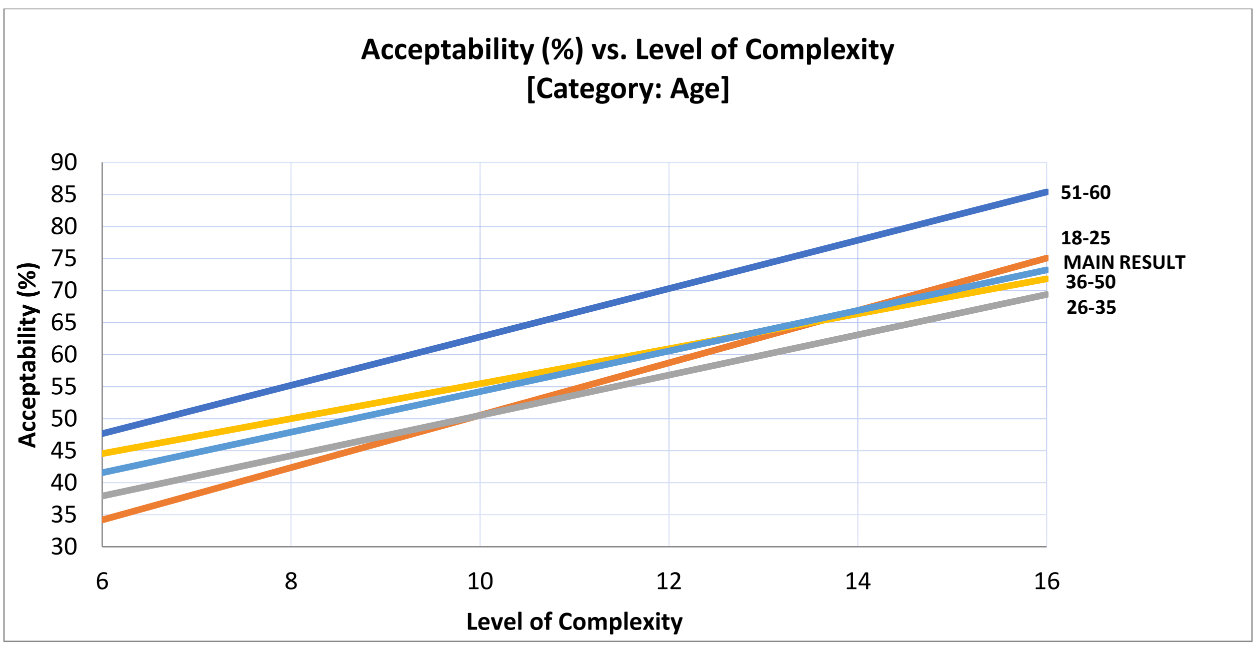

Figure 15: Line Plot for Acceptability vs. Level of Complexity Based on Age

The line plots show that the age group 51-60 has higher acceptability levels overall, whereas the age group 26-35 has lower acceptability levels overall compared to the rest of the population. The age group 18-25 has a much steeper acceptability function compared to other age groups, meaning that their acceptability increases in a higher rate than the other age groups as the complexity level increases. The age group 18-25 makes up around 40% of the respondents; if their percentage was lower, the expected acceptability function would be less steep, but still have similar acceptability levels as the actual main result.

9.2.7. Based on Education Level

In the survey, respondents were asked to mark their education level. The following answers were given:

Table 26: Percent Distribution of Answers to the Education Question

Education (N = 92)	
High school degree	0%
Bachelor's degree	37%
Master's degree or above	63%

The re-estimated acceptability functions for each response group is given below.

Table 27: Re-estimated Acceptability Functions Based on Education

Response Group	Re-estimated Acceptability Function
Bachelor's degree	A = -20.6 + 7.463 CL
Master's degree or above	A = 27.78 + 2.728 CL

The line plots for these acceptability functions are given below.

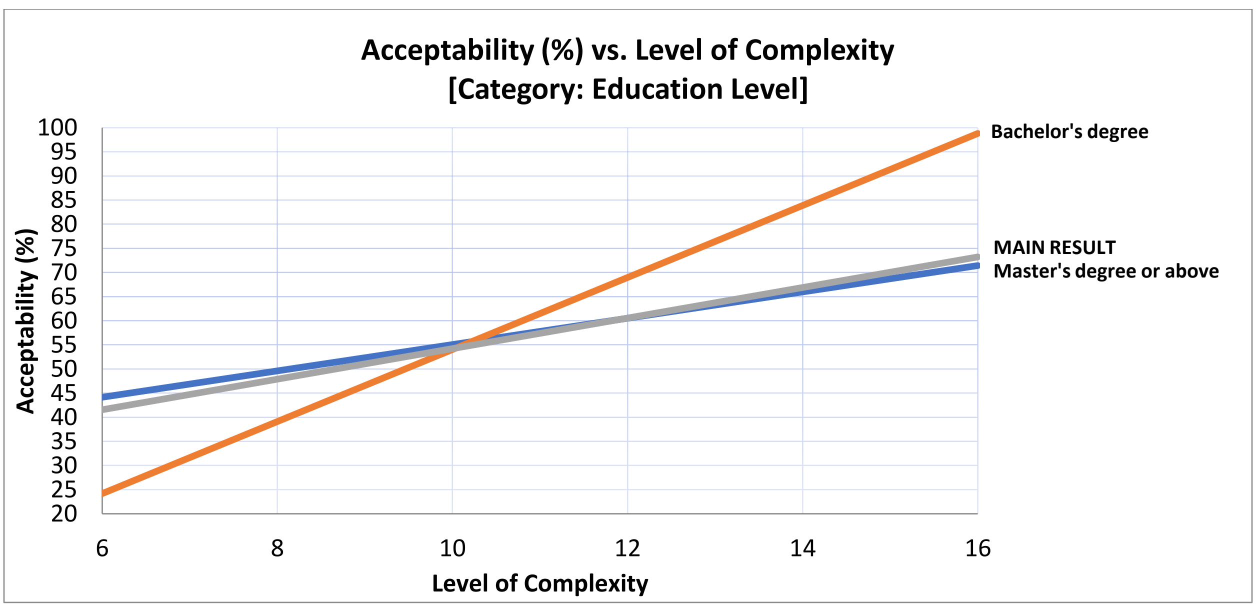

Figure 16: Line Plot for Acceptability vs. Level of Complexity Based on Education

The line plots show that the response group with bachelor's degrees has a much steeper acceptability function. They have lower acceptability levels at lower complexity levels but have higher acceptability levels as the complexity level increases compared to the rest of the population. The response group 'master's degree or above' has a similar acceptability function to the overall main acceptability function; their acceptability levels are stable compared to the main result. This can be interpreted in the way that as the education level increases, acceptability levels become more stable. If there were more respondents with bachelor's degrees, we would expect the acceptability function to be steeper.

9.3. Sensitivity Analysis for the Utility Function

The parameters for effectiveness and acceptability were re-estimated in Biogeme according to the answers given to the question about social norms in the stated choice experiment. The respondents were asked if the reputation of congestion charges affected their decision making. With the new parameters, the utility functions were re-estimated and the differences were observed.

The re-estimated parameters for the response groups are given below.

Table 28: Re-estimated Parameters Based on Social Norms

Response Group	$\beta_{Effectiveness}$	$\beta_{Public\ Acceptability}$
Not at all	0.105	0.0295
Somewhat affected	0.100	0.0360
Considerably affected	0.113	0.0383

An interesting finding among the parameters is that the response group 'considerably affected' has the highest estimated parameters for both effectiveness and acceptability. This can be interpreted in the following way: policy makers - who are familiar with congestion charges and are affected considerably by the reputation of it - tend to give more value to charging plans in terms of overall utility. This is an indication that the reputation of congestion charges must be positive for policy makers in order to affect them in such a way.

The utility functions will be observed for (1) when the effectiveness function is positive and (2) when the effectiveness function is negative.

9.3.1. When the Effectiveness Function is Positive

Based on re-estimated parameters and the positive effectiveness function, the re-estimated utility functions are given below.

Table 29: Re-estimated Utility Functions Based on Social Norms when the Effectiveness Function is Positive

Response Group	Re-estimated Utility Function
Not at all	U = 0.7810 + 0.2032 CL
Somewhat affected	U = 0.8680 + 0.2109 CL
Considerably affected	U = 0.9883 + 0.2395 CL

The line plots for these utility functions are given below.

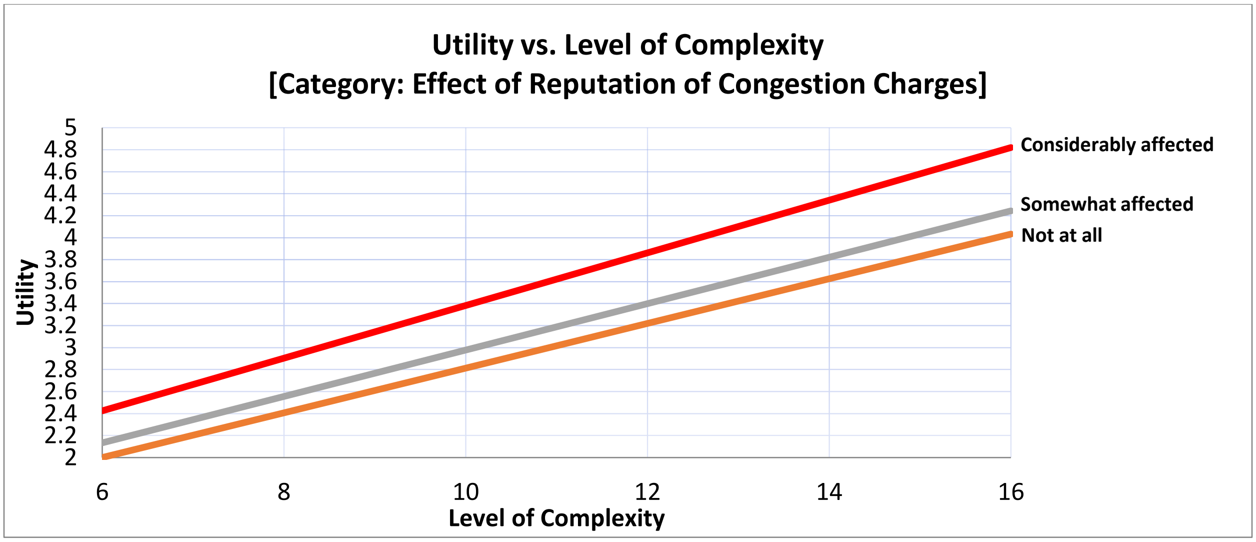

Figure 17: Line Plot for Utility vs. Level of Complexity Based on Social Norms - when the Effectiveness Function is Positive

The line plots show that policy makers - who are considerably affected by the reputation of congestion charges – have higher utilities compared to other response groups. This was expected based on the high parameter estimates for the 'considerably affected' response group. Policy makers – who are not affected by the reputation of congestion charges – have lower utilities overall compared to the rest. Policy makers – who are somewhat affected by the reputation – fall in between those who are considerably affected and not affected at all.

The line plots imply the following: Policy makers who are affected more by the reputation of congestion charges have higher utilities.

9.3.2. When the Effectiveness Function is Negative

Based on re-estimated parameters and the negative effectiveness function, the re-estimated utility functions are given below.

Table 30: Re-estimated Utility Functions Based on Social Norms when the Effectiveness Function is Negative

Response Group	Re-estimated Utility Function
Not at all	U = 3.3609 - 0.0030 CL
Somewhat affected	U = 3.3250 + 0.0145 CL
Considerably affected	U = 3.7648 + 0.0175 CL

The line plots for these utility functions are given below.

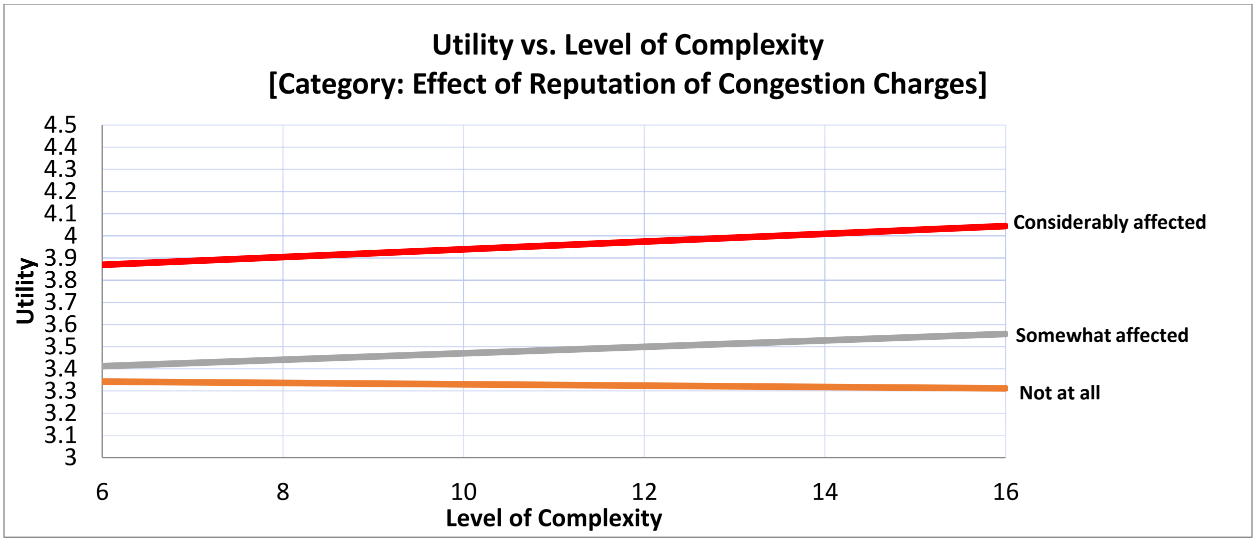

Figure 18: Line Plot for Utility vs. Level of Complexity Based on Social Norms - when the Effectiveness Function is Negative

The line plots show that the policy makers – who are considerably affected by the reputation of congestion charges – have higher utilities. In terms of utility levels for response groups, the results are the same as when effectiveness function was positive. However, there is one difference: the response group 'not at all' has a slightly negative utility function. This can be interpreted in the following way: policy makers – who are not affected by the reputation of congestion charges at all – give a low parameter estimate for acceptability such that the negativity of the effectiveness function cannot be overcome in the utility function. Though, the slope of this negative utility function is very insignificant. For the 'not at all' response group, the utility is 3.34 for level 6 complexity, and it drops to 3.31 for level 16 complexity. The utility changes only by 0.03 units. This is not a significant change compared to the range of other utility functions, for instance, when the effectiveness function is positive, the utility varies between 2 and 5.

9.4. Conclusion

The sensitivity analysis shows that all response groups have positive acceptability functions. This proves that the main acceptability function is robust. **Therefore, it can be concluded that acceptability increases as the complexity level increases, from the perspective of the public, no matter the age, sex, education level or other types of categories.**

On the other hand, sensitivity analysis for the utility functions show that with the exception of one case, all observed utility functions are positive. That one case occurs for policy makers – who are not affected by the reputation of congestion charges – given that the effectiveness function is negative. Even in that one exceptional case, the negativity of the utility function is not significant; the utility changes by only 0.03 units which is very small compared to the overall scale of utilities. This finding implies that the utility function is robust in its direction. **Therefore, it can be concluded that utility increases as the complexity level increases, from the perspective of policy makers.**

10. Discussion & Conclusion

In this chapter, conclusion to the entire research is provided, limitations to the research are discussed and implication of results for policy design is given.

10.1. Conclusion

The main research question of this thesis research was*: What is the relationship between congestion charging complexity levels and utility in terms of the effectiveness of the congestion charge and the public acceptability level, from the perspective of policy makers?*

As the answer to the main research question, **it can be concluded that utility increases as the complexity level increases, from the perspective of policy makers.** Sensitivity analysis shows that this finding is robust.

As the answers to the sub questions, **(1)** there is no proof to suggest a significant relationship between complexity and effectiveness in any direction; **(2)** the relationship between complexity and acceptability is positive and the relationship is statistically significant; acceptability increases as complexity increases, from the perspective of the public (respondents of the survey); sensitivity analysis shows that this finding is robust; **(3)** the ratio – tradeoff – between the effectiveness parameter and the acceptability parameter ($\beta_{effectiveness}$ / $\beta_{aceptability}$) is 3.11; effectiveness parameter is estimated to be significantly higher than the acceptability parameter from the perspective of policy makers.

10.2. Limitations and Future Work

Limitations are separated into two groups: key limitations and other limitations. Key limitations have the potential of significantly changing the results of this research if such limitations did not exist; other limitations refer to limitations that sllightly affected the results but did not significantly change them in my opinion.

Key Limitations

(1) Scarcity of Data

One of the primary limitations in this thesis research was the difficulty of investigating the relationship between effectiveness and complexity. Previous studies that looked into this relationship had used models based on survey data. However, given funding and long research periods, those studies [(Department for Transport, 2004), (Bonsall, Shires, Ngoduy, et al., 2007), (Link, 2015)] could not conclude a strong relationship between complexity and effectiveness. In addition, using survey data does not accurately represent real-life choices that people make. Thus, instead of doing a similar survey as previous studies did, I chose to investigate if there was a relationship between complexity and effectiveness in real-life congestion charge implementations. If there was a visible trend among real-life congestion charge implementations, it could hint that there was a significant relationship between complexity and effectiveness.

There was a fundamental limitation when analyzing real-life congestion charging implementations and that was the scarcity of data. Successful implementations for which the data was available were limited to only five cases (Börjesson & Kristoffersson, 2015). Observing five cases would nowhere near be enough to do an inductive statistical analysis, let alone provide proof for a significant relationship. Nonetheless I investigated those cases in detail and performed a regression analysis; and unfortunately, there was no indication of a positive or negative trend. Observing different cases provided different results.

For someone who is not familiar with congestion charges, choosing cities where congestion charges successfully reduced the congestion might seem like a selection bias. However, this is not the case, because to my knowledge, there is not a single case of congestion charging case that doesn't reduce congestion. Congestion charging is proved to be an efficient means to reduce congestion.

(2) Unaccounted Factors that Influence Effectiveness

Another key limitation is that there are a lot of factors that influence effectiveness other than complexity; and in my analysis, I tried to limit the effects of those other factors. I took into account the initial congestion levels – which Börjesson et al. (2014) states as the most important factor influencing effectiveness – and the cost of the charges. However, the inconsistency of results based on observing different cases shows that there are other factors that influence effectiveness which I did not account for. A very important unaccounted factor might be the policy objective. Bonsall et al. (2007) state that people's behavioral changes can depend on the policy objective and how it was revealed to them. The examples of Stockholm and Gothenburg support this theory. Stockholm and Gothenburg adopted very similar congestion charges with the same level of complexity, but their policy objectives were different. Stockholm aimed at reducing congestion whereas Gothenburg aimed at reducing congestion but also equally important at gathering revenue for public investments. Stockholm had significantly higher reduction in congestion (22%) compared to Gothenburg (12%) within the first year after implementation. The unaccounted factor of policy objective made the analysis of real-life congestion charging implementations more difficult than it already was.

Due to the limitations given above (1 & 2), the relationship between complexity and effectiveness does not have a conclusive direction. Therefore, for the utility, I covered both cases when the relationship between complexity and effectiveness was both positive and negative. I used the effectiveness functions that resulted from the analysis of real-life congestion charging implementations. The reason behind using those functions is that I use the same complexity definition for the acceptability part of the utility, so it would be consistent if both parts of utility (effectiveness and acceptability) used the same definition of complexity.

<u>**Other Limitations**</u>

(3) Definition of Complexity

Using the same definition of complexity for effectiveness and acceptability makes my research consistent; however, there is a limitation in that too. Recall that, complexity levels – as defined in this thesis research – has three attributes: number of dimensions, number of levels in those dimensions and the number of exemptions / discounts. I quantified the complexity levels of real-life charging plans with this definition. Real-life charging plans had various dimensions and the levels within those dimensions varied. For instance, in Stockholm, the 'time' dimension had 2 levels and the 'location' dimension had 1 level. I used the complexity levels of real implementations in my analysis of complexity vs. effectiveness. On the other hand, for the analysis of complexity vs. acceptability, I used a different approach. I limited the alternatives that I presented to respondents in the following way: number of levels of dimensions were always either

1 or 2. This resulted in 16 different alternatives. I did this in order to limit the number of alternatives, so that the rating experiment would be doable in the time span I had. If I had not done this, the number of alternatives for complexity levels would be overwhelmingly high, and the rating experiment would not be performable. This approach that I used results in the following problem: The alternatives that the respondents were presented in the rating experiment have complexity levels structured such that they can possibly exist in real life, but do not exist in the set of real-life observations I had. This limits my research in the following way: for instance, a complexity level of 10 can be structured in multiple ways; and there might be such structures that might result in different acceptability levels than the ones I had for the complexity level of 10 in my research. However, I do not think that this limitation changed the direction of acceptability, because higher complexity levels – no matter how they are structured – have more variance in them, and they are objectively more complex than lower levels; thus, the difference between lower complexities and higher complexities would still be the same in terms of acceptability.

(4) Accounting for All Choices in the Rating Experiment

Another limitation regarding complexity vs. acceptability is that the rating experiment does not completely account for people who are against the idea of congestion charges. I use the word ‘not completely’ because to some degree those people are accounted for. For instance, when I was manually handing the surveys, I observed ratings which consisted of complete zeros for each alternative. I asked the person why she rated each complexity level with ‘0’; she said that she completely detests the idea of congestion charges. Therefore, to some degree, people who are completely against congestion charges are accounted for. Ideally, respondents are expected to rate each alternative independently; however, there might be some respondents who voted each alternative in comparison to other alternatives. This might have caused acceptability levels to appear higher than they are.

(5) Scope of Public Acceptability

In previous studies, such as (Schade & Schlag, 2003) and (Fürst & Dieplinger, 2014), the acceptability levels represent only the opinion of drivers and motorists, the people who are directly affected by congestion charges. However, in this thesis research, when I estimate the utility, I use the acceptability function of the entire respondents, not just drivers. There are two reasons for doing this: (1) In case of a referendum about whether to implement congestion charges or not, the entire public is going to vote, so it is more important for policy makers to take into account the entire acceptability level, rather than just the acceptability level of drivers. (2) The effectiveness component of the utility applies to the entire public; reduction in congestion does not just affect drivers, but also people who use public transport and also the residents who would experience less noise and pollution. The utility would be in consistent if I used the entire public as basis for effectiveness and only drivers as basis for acceptability. Therefore, I used the acceptability function of the entire respondents in the utility estimation.

(6) Hypothetical Component of the Stated Choice Experiment

Another limitation occurred at estimating the parameters of the utility function from the perspective of policy makers. The utility function has two parameters: effectiveness parameter and the acceptability parameter. I performed a stated choice experiment to estimate those parameters. Making the tradeoff between effectiveness and acceptability is the job of policy makers; however, instead of performing the survey with real politicians, I asked respondents to put themselves into the shoes of policy makers in the survey. Using real politicians for the stated choice experiment could provide more accurate results.

Actually, Chorus et al. (2011) in a paper regarding politicians' preferences for road pricing policies, performed a stated choice experiment among real politicians; and in their research, they also estimated parameters for effectiveness and acceptability. In this thesis research, $\beta_{effectiveness}$ / $\beta_{aceptability}$ is 3.11; in Chorus et al. (2011)'s research, $\beta_{effectiveness}$ / $\beta_{aceptability}$ is 2.63. This comparison shows that I estimated the effectiveness parameter a bit higher. However, the results of both this thesis research and Caspar et al.'s research indicate the same thing: effectiveness parameter is estimated to be significantly higher than the acceptability parameter. Therefore, the limitation that I had regarding the stated choice experiment did not cause a drastic difference in the overall results of this thesis research.

(7) High Education Level Amongst the Respondents of the Survey

The demographics of the survey show that all of the respondents had at least a bachelor's degree. This creates a skewed representation of the actual public. High educated people might cope with higher complexities more easily than less educated people. This might inflate the public acceptability levels that I measured. However, I do not think that this would drastically change the relationship between charging complexity and public acceptability; because the sensitivity analysis shows the direction of this relationship stays the same among people with master's degree (and above) and people with bachelor's degree, with the only difference being that people with bachelor's degrees have higher variations in their acceptability levels. Thus, we can expect that people who are less educated (compared to a bachelor's degree) will have even more variation in their acceptability levels, but the direction of the relationship between complexity and acceptability will remain the same.

(8) Level of Complexity in Regards to ICT

Advancements in information and communications technology allows us to reach information in fractions of seconds. Nowadays, there are lots of navigation apps that allow people to access real-time information about routes and prices. It is safe to assume that such applications will also contain information regarding the congestion charges. How does this ease of accessibility to information affect complexity? Does it make congestion charges less complex? In my opinion, the answer is no; ease of accessibility does not reduce the complexity of a charging plan. There are two reasons for this: (1) Reaching the information about costs through apps does not affect complexity at all, it only changes the medium of reaching that information. It will only take a few seconds with navigation apps to know how much it would cost; on the other hand, without apps, it would take longer, you would maybe call the municipality or check old newspapers, yet still you would reach that information. If the congestion charge has a high level of complexity, you would use the navigation app more often or if apps did not exist, you would reach that information through other means, but regardless the key point is that you would do it more **often**. Vice versa, if the congestion charge has a low level of complexity, you would put less effort into reaching information about costs. Higher complexities would cause more discontent when it comes to knowing the costs regardless of whether you are using a navigation app or some other means, because whatever it is you are doing, you would do it more often. (2) Complexity is not only about predicting the charges. In the theoretical frame chapter, I discussed the issues of fairness and predicting charges. Depending on how a congestion charge is presented to people, people can look at it from a perspective of fairness or from a perspective of predicting the charges. In this thesis research, fairness seems to weigh heavier than predicting the charges, because the results show that there is positive relationship between complexity and acceptability. Therefore, the acceptability of different complexity levels is not only about knowing how much it costs.

Navigations apps make it easier to reach information, however it would not influence public acceptability levels of a congestion charging plan. I also think that it would not influence the effectiveness of a congestion charging plan either. Effectiveness of a congestion charging plan regarding its complexity is related to predicting charges and how people behave based on that; the highlight being on the word "predicting". Once you stop "predicting", it does not really matter what kind of device you use to reach that information, because at that point your concern would stop being about the level of "complexity" and be more about the level of "prices". Overall, I do not think that use of ICT in relation to congestion charges will make congestion charges less complex or change the results of this thesis research.

(9) Linearity of Results

The effectiveness function, the acceptability function and the utility function which I estimated are all linear functions. Their linearity was not my own choice, but the determination of the statistical software Minitab that I used. The software provides the function that represents the data the best. The utility function which provides the answer to the main research question has a linear nature and suggests that utility increases as the complexity increases, from the perspective of policy makers. The levels of complexity that I used in this research ranges from 6 to 16. This might create a limitation regarding the linearity of results. If I had used a larger range – let's say from level 6 to level 26 – would the utility function be still linear or would it reach maximum at some point and curve down? If we look at the average acceptability vs. level of complexity graph below; it is visible that the variation in acceptability among the top quartile of complexity levels is much lower compared to the variation among lower level of complexities.

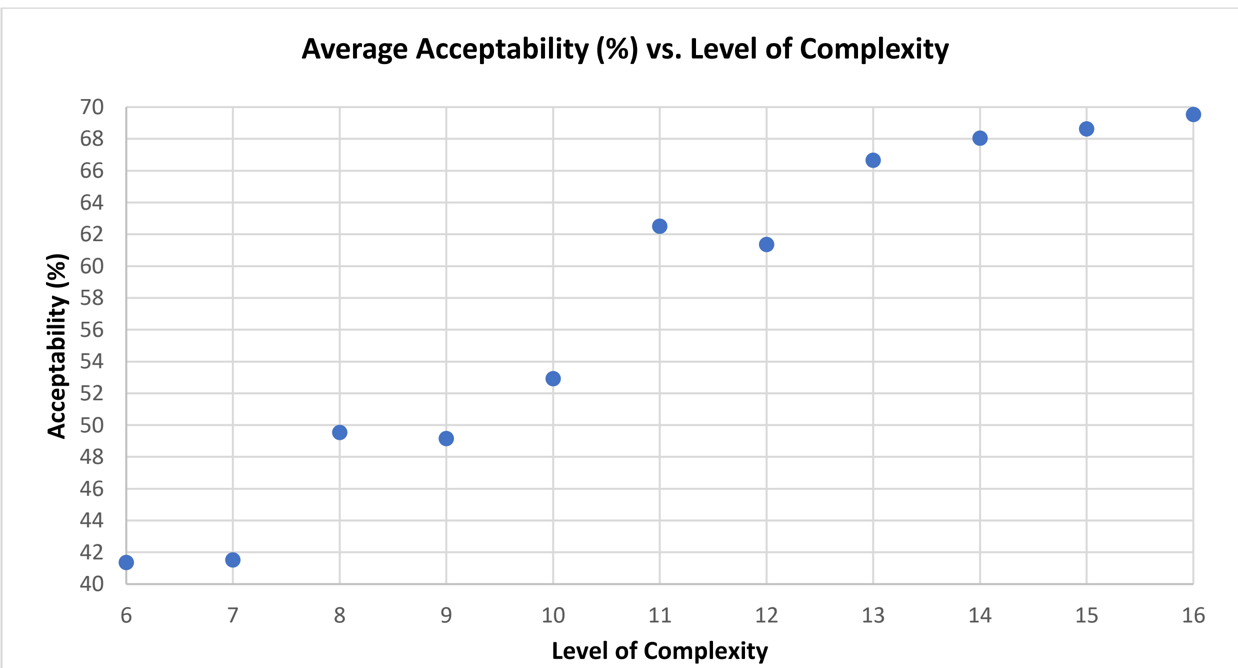

Figure 19: Average Acceptability (%) vs. Level of Complexity

There is a strong inference in the graph that if the survey included higher levels of complexity above 16, acceptability would peak and then curve down. With the data that I had, the software determined that the relationship between acceptability and complexity was linear. If I had more data about much higher complexity levels, there is a chance that the software would determine a non-linear relationship. In that case, the utility function would also become non-linear, because it is derived directly from the effectiveness and acceptability functions.

I made the deliberate decision to limit the complexity levels between 6 to 16, because in the analysis of real-life congestion charging implementations that I performed (given in Appendix I), the complexity levels of real-life congestion charge plans ranged between 10 and 14. Therefore, in order to stay realistic, in the surveys I used complexity levels close to those of real-life levels.

Does this limitation significantly affect the results of this thesis research? In my opinion, the answer is no, it does not. Even if we assume that the relationship between utility and complexity is non-linear given that we include much higher complexity levels; a logical policy maker would not even consider those extremely higher complexity levels to start with. Any complexity level after a certain point would be discarded. In my opinion, a logical policy maker would not try to implement a charging plan with a complexity level of 24, whereas the maximum complexity level in real-life implementations is 14. Therefore, I stick with my original conclusion, which is that policy makers should opt for higher complexity levels; because I assume that absurdly high complexity levels (which cause non-linearity) will not be included in the decision-making process to start with.

Future Research

If I had a longer time span and access to larger opportunities at conducting surveys, this is how I would design this thesis research: First of all, the factors that influence effectiveness other than the complexity of the charge should be researched in depth. Without eliminating the effects of those other factors, finding a significant relationship between complexity and effectiveness is not likely. I addressed some of those other factors, such as the initial congestion level and the cost of the charge. However, I think another very important factor that needs to be investigated is the policy objective. The influence of policy objective on effectiveness should be researched in depth. In addition, analyzing real-life charging implementations does not yield a strong result because of the scarcity of data; therefore I would go back to the method that GRACE project used – as explained by (Bonsall, Shires, Ngoduy, et al., 2007) – which is to create a model based on surveys regarding the behavioral changes of people. In those surveys, as opposed to GRACE project, I would not ask respondents about the complexity of the charge, because that creates a negative perception if the charge is complex, which affects people's decision making. Instead I would provide respondents with charging plans which vary according to the complexity level definitions which I used in this thesis research – which are not based on people's perception, but are objectively more complex as the variation increases –.

My definition of complexity levels can be further developed, by investigating how each dimension and levels within those dimensions, exemptions and discounts contribute to the complexity. I assumed that an increase in any level in any dimension would increase the complexity in the same amount. However, some dimensions might actually contribute more to the complexity than others. I believe a whole research should be devoted to this issue; and then a better complexity level definition can be achieved.

Regarding complexity vs. acceptability – in other words the rating experiment – this is how I would do things differently: In the rating experiment, I asked respondents to rate different charging plans, but I defined those charging plans in short sentences and without giving much detail. This was a necessary design at the time, because this shortened the time to complete the survey and allowed me to reach more respondents. However, if I was to redesign the rating experiment, I would give each respondent a detailed description of several charging plans which vary according to complexity levels. The detailed descriptions would include time tables, costs, maps and more information about how it was thought to be implemented. The respondent would take those charging plans home, and study them for a few days. After a few days, the respondent would be contacted again and asked to rate those charging plans. By giving more information to the respondent and some time to study it, we can also observe the battle between fairness and labor of predicting charges. In the theoretical framework chapter, I explained that respondents, when not asked about predicting the charges upfront, might focus more on fairness of the charge. While respondents are studying the charging plans for a few days, it can be expected that they will think over about both issues, although unknowingly. After collecting the data from the survey and analyzing it, based on the results we get, we can more accurately state which of the two issues dominated people's acceptability. For instance, if the acceptability levels are similar to this thesis research, it can be concluded that people intuitively value fairness more than predicting charges or vice versa. An experiment like this would spread over a long amount of time and need funding because of the practical difficulties of conveying the survey.

Regarding the stated choice experiment, if I were to re-do it, I would conduct the survey with actual politicians. However, reaching to enough politicians to complete the survey is a difficulty on its own. In order to do the stated choice experiment properly, I would need access to a network of people within the municipalities and transport ministries.

I used two parameters for my utility function, but the number of those parameters can be augmented. In future researches, other parameters can be included such as operational costs and emission reductions. In this research, a RUM based linear additive utility model was used, but a future research can use a mixed logit model which would capture taste heterogeneity or a random regret minimization model like Chorus et al. (2011) used in their research.

10.3. Implications of Results for Policy Design

10.3.1. Stakeholder Analysis

There are three major group of actors when it comes to the implementation of congestion charges: the people living in that certain city in other words the public, the policy makers and the media. The public can be separated into two groups based on whether they will be directly affected or indirectly affected from congestion charging. People who will be directly affected are the ones who drive cars as their primary mode of transportation inside the city center where the congestion zone is planned to be implemented. People who will be indirectly affected are the ones who use different modes of transport, such as public transport (buses and trams) and bikes. Indirect effect means that they are not going to be required pay congestion charges, but nonetheless they are affected, because of the traffic congestion in the region. The other major actor group is the policy makers in other words the politicians who can be from the municipality of that given city or the ministry of transport of that country. (The words 'policy makers' and 'politicians' are used interchangeably, although I acknowledge there are differences between the two.) The media, which plays an intermediary role between the policy makers and the public is also an important actor. Ardıç et al. (2013) state that for instance in the Netherlands, Dutch media was not objective in previous road pricing debates and acted as a policy actor. Perspectives of each actor are investigated below.

Drivers' Perspective

As part of the public, any reasonable assumption would suggest that drivers would like to have a congestion plan that is acceptable to them. Drivers, as a group of people, will have differences among their opinions; some of them will be completely against congestion charges, some will support it and some would fall in between. However, if there is a policy debate, and a congestion charging plan is intended to be implemented, they would prefer a plan that has high acceptability. Therefore, we can state that the main goal of drivers is to have a congestion charging plan which would have a high acceptability level.

In relation to complexity levels, it means that they would prefer higher complexity levels; since higher complexity yields higher acceptability according to the results of this thesis research. Their acceptability levels range between 45 and 75 and are only slightly higher than the acceptability levels of the overall population. This provides an insight to their attitude / interest. In terms of attitude, it can be interpreted that drivers do not have an enthusiastic attitude (an enthusiastic attitude or a strong interest for instance would occur if acceptability levels of a group is significantly above the average of that population), but their attitude is also not very negative; acceptability levels start below 50 but gradually increases with complexity. It can be interpreted that they have a mediocre attitude towards congestion charging plans.

In terms of power, drivers as part of the public have no power at all. Börjesson, Eliasson and Hamilton (2016) on their paper about the Gothenburg congestion charge, state that the acceptability level of the public was around 33% before any trial implementations, after the trial period, there was a referendum about whether to keep the charges or not and the acceptability was only 43% which means that the majority of the public rejected it; however, the politicians decided to keep the charges regardless of the rejection by majority. This shows that the public has no real power at all when it comes to the implementation of congestion charges.

Non-Drivers' Perspective

Similar to the drivers, as part of the public, non-drivers would also prefer a congestion plan that is acceptable to them. Perspective of non-drivers is important for two reasons: (1) although indirectly, they are still affected by the congestion charging plan, because traffic congestion also influences public transport, (2) in case of a referendum about implementing congestion charges, non-drivers will also vote. Similar to the drivers, we can state that the main goal of non-drivers is to have a congestion charging plan which would have a high acceptability level.

In relation to complexity levels, it means that they would prefer higher complexity levels; since higher complexity yields higher acceptability according to the results of this thesis research. The acceptability levels of non-drivers range between 42 and 73 which are slightly lower than the acceptability levels of the overall population. This gives an insight to their attitude / interest. It can be interpreted that non-drivers do not have an enthusiastic attitude or strong interest, but they do not have extremely negative attitudes as well. Overall their acceptability level starts at 40, but goes over 50 pretty quickly as the complexity increases, on average the majority would be on the positive side when accepting congestion charges. Their attitude and interest can be described as mediocre, but compared to drivers, it would be slightly lower due to lower acceptability levels.

In terms of power, non-drivers have no power when it comes to decisions about congestion charging implementations, similar to the drivers.

Policy Maker's Perspective

In a paper about politicians' preferences for road pricing policies, Chorus et al. (2011) states that according to public choice theory, policy makers, in other words politicians, when they interact with other actors such as the voters (in our case the public), pursue their own goals. Chorus et al. (2011) also explains that politicians are inclined to support road pricing policies which are in line with their own interests, such as re-election and increasing personal income. In that same paper, Chorus et al. (2011) discusses that politicians are reluctant to introduce road pricing policies based on the assumption that their primary interest is re-election. There are two main reasons why politicians are reluctant. First of all, the solution of problems by introducing a road pricing is not attributed to the actions of politicians but instead attributed to the actors in the market with invisible roles for the price incentive (Chorus et al., 2011). Therefore, the politicians think that their efforts are not recognized, so they become reluctant. Secondly, politicians think that while the costs of road pricing are highly visible, the reduction in congestion and improvements on environment is much less visible. This causes politicians to be associated with negative sides of road pricing and therefore negatively affects their chance of re-election, so they become reluctant to introduce road pricing. So far, it can be interpreted that the attitude of policy makers is reluctant and their interest is low. However, there are some cases in which the policy makers turn road pricing policies into an election promise (Vonk Noordegraaf, Annema, & van Wee, 2014). In such cases, the attitude of the policy maker can be described as enthusiastic and their interest would be high. Therefore, the attitude and interest depends on whether the road pricing policy is an election promise or not. For the sake of this stakeholder analysis, it will be assumed that road pricing policy is not an election promise; therefore, the interest is low and the attitude is reluctant.

Chorus et al. (2011), in the same paper mentioned above, also performed a stated choice experiment in which local politicians were respondents. That stated choice experiment had five parameters: emission reduction, congestion reduction, operational costs, acceptability among retailers and acceptability among public. Two of those parameters are the same as in this thesis research: congestion reduction (effectiveness) and acceptability among public. They run their data in Biogeme with a utility-based RUM model same as in this research and they have estimated the following parameters:

	Utility-based model	
	Beta	*t*-value
Emission reduction	1.180	4.87
Congestion reduction	0.791	4.25
Operational costs	−0.784	−3.09
Acceptability (retail)	0.344	2.91
Acceptability (inhabitants)	0.301	2.79
Number of observations	238	
Null-LL	−261.5	
Final-LL	−240.2	
Rho-square	0.08	

Figure 20: Parameter Estimates of Politicians' Preferences for Road Pricing Policies. (Chorus et al., 2011)

There is a strong resemblance with the ratio of parameters that I estimated in this research and with the parameters that Chorus et al. (2011) estimated. The ratio between the effectiveness parameter and the acceptability parameter (in other words, tradeoff between effectiveness and acceptability) I estimated was $\frac{\beta_{Effectiveness}}{\beta_{Public\ Acceptability}} = 3.11$. The ratio that was estimated in their paper is, 0.791 / 0.301 = 2.63. Those two numbers, significantly suggest that effectiveness is estimated highly over acceptability in both cases. Note that in this thesis research, respondents were asked to put themselves into the shoes of policy makers during the stated choice experiment. Therefore, such resemblance in both estimates is expected. This suggests that we can use our main utility function as the utility of hypothetical policy makers and we can use it to interpret the perspective of politicians. Politicians give more value to effectiveness than acceptability in terms of utility. We can state that the main goal of politicians is to have a congestion charging plan with high effectiveness and an acceptability level which would not give damage to their chances of re-election.

In relation to the complexity levels, they would prefer higher complexity levels due to better utilities based on the results of this thesis research.

In terms of power, policy makers are very powerful compared to the public. As stated in the paper by Börjesson, Eliasson and Hamilton (2016), even if acceptability levels are low and the majority of people reject a congestion charging plan, policy makers can still decide to implement it.

<u>The Media's Perspective</u>

Whether or not the media is a policy actor is a debatable issue. Ardıç et al. (2013) on their paper regarding this issue, conclude that within the scope of Netherlands, Dutch media was not objective and acted as a policy actor. The perspective of the media depends on the views of that certain media organization; for instance, whether they are liberal or conservative. Therefore, the goal of the media regarding the support/opposition for congestion charging implementations, depends on the world views of that respective institute. However, a common goal can be stated for the media regardless of support or opposition, and that is to inform the public about policies. The attitude of the media in terms of reporting is enthusiastic and their interest is high; we see this from the amount of coverage in the media after certain policy events (Ardıç, Annema, & van Wee, 2015). In terms of power, the media does not have direct power on implementing congestion charges; however, they can stimulate the public debate and contribute to the final decisions by the policy makers. Therefore, we can say that they have more power than the public, but less power than policy makers.

Based on the actor perspectives, the following stakeholder - goal table is achieved.

Table 31: Stakeholder - Goal Table

Stakeholder	Power	Attitude	Goals
Drivers	.	+	High acceptability
Non-Drivers	.	+	High acceptability
Policy Makers	++	.	High effectiveness, acceptability and no damage to re-election
The Media	+	++	Inform the public
Legend: '**++**': high, '**+**': medium, '**.**': low.			

Based on actor perspectives, the following power – interest matrix is achieved.

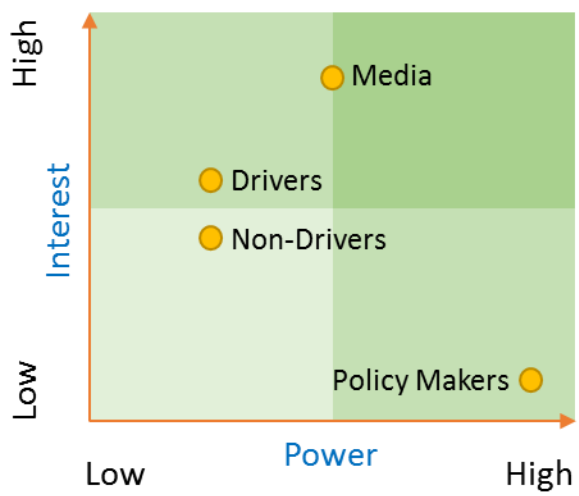

Figure 21: Power - Interest Matrix of Actors

Implication of this stakeholder analysis together with the implication of results for policy design are discussed in the next section.

10.3.2. Implications for Policy Design

Based on the results of this thesis research, a high level of congestion charging complexity is desirable for both policy makers and the public; because (1) utility from the perspective of policy makers increases as complexity increases and (2) acceptability from the perspective of the public increase as complexity increases.

With a congestion charging plan with high level of complexity, drivers and non-drivers would reach the desired goal of high acceptability as given in the stakeholder analysis. In the same situation, with a high level acceptability, policy makers would also minimize the damage to their re-election. Policy makers would also aim for high effectiveness and regardless of whether complexity influences effectiveness positively or negatively, the tradeoff between effectiveness and acceptability suggests that a higher complexity provides a better utility. Therefore, in a situation, where complexity is anticipated to influence effectiveness negatively, policy makers should still choose a higher complexity level.

The stakeholder analysis suggest that policy makers have low interests in introducing congestion charging plans. This suggests that they would only act if there is enough pressure from the public and the media. However, once the option of introducing a congestion charging plan is on the table, policy makers have the highest power. However, this does not mean that the policy makers can design the policy in any way they want. Policy makers should be in touch with other actors at all times in order to design a policy that is favorable to all, not only on the aspect of complexity, but also on other aspects of the congestion plan as well. If we describe a process design that starts with the initiation of a policy debate and ends with the implementation of congestion charges, the following core elements of a process design should be adhered, as defined in the book on process management by de Bruijn, ten Heuvelhof and in 't Veld (2010): (1) openness; meaning that other parties are offered an opportunity to bring up issues and steer the decision making, (2) protection of core values; meaning that the core values of the participating parties should not be harmed, regardless of the outcome of the process, (3) progress; meaning that it should be ensured that the process does not become sluggish and always has sufficient momentum and progress, and (4) substance; meaning that the process should have a sufficient number of substantive elements (de Bruijn et al., 2010).

Regarding the relationship between actors, the media plays an extremely important role. Given that the main policy objective is to reduce congestion, Bonsall et al. (2007) states that, in order to get a high level of effectiveness, public's ability to understand the charging plan should be maximized by investing significantly in publicity. This implies that the policy makers should have a good relationship with the media. The media plays the role of an intermediary actor between the policy makers and the public. Policy makers should reveal their charging plans in plain terms and clearly explain the essence of the plan, help people understand the complexity level of the plan and how to respond to it. A good relationship between the media and policy actors ensure that the charging plan and the complexity levels will be clearly understood by the public.

In conclusion, based on the results of this thesis research, policy makers should favor charging plans with high level of complexity in their designs; they should include other actors in the design throughout the process; they should have a good relationship with the media and use them to explain the essence of the charging plan and the reasoning behind the chosen complexity level as clearly as possible to the public.

11. Epilogue

In the process of performing this this thesis research, I managed with many difficulties on the way. Perhaps, the hardest part of it all was to structure the methods and how to approach the research question. Initially I was planning to perform a multi criteria analysis to estimate the acceptability and effectiveness parameters, but based on the advice of my full professor, I performed a stated choice experiment, along with the rating experiment. I had taken related courses about statistical experiments; however, performing one myself was a whole new experience. Ngene software that I used to create efficient designs and Biogeme software which I used to analyze the data from stated choice experiments were all unknown territories for me. Learning how to perform these experiments and learning to use the software was an enjoyable experience. I mean the word 'enjoyable' in its true meaning, because this thesis topic was born out of my own effort, so I every step of the way I was doing something that I wanted to do, and seeing this research providing answers to the questions that I asked gave me nothing but pure joy. My research skills have developed immensely. Scanning the literature for relevant information and using that information to structure my thesis became an easier process as time passed. One of the lessons that I learned from this research is that sometimes, there are no black and white answers to the questions we ask and that does not reduce the importance of asking that question. For instance, the relationship between acceptability and complexity levels was very robust as it endured in the sensitivity analysis, so the answer to that sub question was very clear; however, there wasn't enough proof to suggest a significant relationship between complexity and effectiveness in any direction. My academic writing skills also increased, getting feedback from my full professor and supervisors helped me do better job when it comes to putting my findings into words. In conclusion, performing this thesis research developed my problem-solving skills, research skills and academic writing; and in all honesty, I enjoyed each and every step of it.

Appendix I: Analysis of Real-life Congestion Charging Implementations Regarding Complexity vs. Effectiveness

1.1. Research Design Choices

- The number congestion charge implementations investigated is limited to five. The reason behind the limitation is that the detailed analysis of the traffic effects have only been published in the following five cities: Stockholm, Gothenburg, London, Milan and Singapore (Börjesson & Kristoffersson, 2015).
- The effectiveness refers to the average reduction in traffic volume during charging hours. Reduction in traffic volume is used interchangeably with 'reduction in congestion'.
- The time scope of effectiveness is limited to 6 to 12 months. This means that the influence of complexity on effectiveness is only investigated for the first 6 – 12 months of the implementation. The reason for this choice is that the long-term effects of congestion charge implementations are not available for all cities, the immediate effects on the other hand are available. For instance, in Gothenburg, congestion charges were implemented recently in 2013, and whereas the immediate first year effects are available, mid-term and long term effects are not available because of the immaturity of the implementation. The well establishment of the immediate first year effects also increases the comparability of different implementations. The definition of immediate effects differs from case to case, between 6 to 12 months.
- For the regression analysis, there are four variables in total which are the complexity level, effectiveness of the congestion charge, the initial congestion level and the cost. The latter two are added to constrain the effect of outside factors on effectiveness.

  Based on Börjesson et al. (2014)'s remarks, the most important variable that determines the effectiveness (reduction in congestion) is the initial congestion level. Therefore, it was included as a variable. The initial congestion level refers to the congestion levels just prior to implementation. Initial congestion level in this research is measured as the average traffic volume passing through the congestion zone per day within times of the congestion charge per kilometer square in the 12 months prior to implementation. There are other ways to measure congestion levels, such as the duration of rush hours or hours of extra travel time or the average time spent per trip. However, those types of data were not available, so I chose to define the congestion level as traffic volume per kilometer square.

  Another variable which aims to constrain outside effects is the cost. The costs are standardized as the maximum charge that can be paid in a day. The maximum charge was chosen as the cost representative because compared to the average charges paid by users, it is not time dependent within the day, because of this it provides a more standardized estimate. For instance, if average charge per user was to be calculated, it would depend on the volume of traffic and also the time intervals; maximum charge on the other hand is independent of those. The costs are converted to US dollars from their original currency based on the currency rate at the first day of their implementation. In order to measure costs across countries, the costs were further standardized as the percentage of gross domestic product per capita of that country at the year of implementation. US dollars was chosen as the currency, because most of the data on GDP are provided in US dollars. Based on these four variables, a regression analysis is going to be performed, using Minitab statistical software.

Initially another constraining variable was planned to be included, which was the market share of public transportation prior to the implementation of charges. This was planned, because Börjesson and Kristoffersson (2015) provide the assumption that this variable is an important factor when comparing the congestion charge implementations in Stockholm and Gothenburg. However, Borjesson and Kristofferson refence the paper of Santos (2005) which compares the congestion charges in London and Singapore, and according to that paper the level of public transport level is not measured by the market share, but by the accessibility of it. Prior to all congestion charging implementations, there are steps taken to increase the accessibility of alternative modes, which in all cases include public transport. In all congestion charge implementations, new bus routes were introduced or the frequency of existing buses was increased. Thus, the accessibility in case of modal shift was already well planned. In addition to this, in another paper, Börjesson et al. (2014) state that changes in public transport supply virtually has no effect on reducing the congestion, contrary to expectation. Based on these findings, initial public transportation level (market share) was removed from this research as a variable.

1.2. Drawbacks

There are a few drawbacks that can cause unexpected errors, their definition and if they were able to be constrained are given below.

- First there is the issue of comparability of different congestion charging plans. In the literature overview in Chapter 2, the issue of comparability was investigated. Börjesson et al (2014) in their paper 'Not invented here: Transferability of congestion charges effects' suggest that the experiences of cities which implemented congestion charges are transferrable without the doubt on whether local features have significant impacts or not. This transferability feature of congestion charging plans also implies that they can be compared. However, aside from local features, other factors also influence the effectiveness. In order to make the complexity levels comparable, those other factors were included as variables in the regression analysis, which are the initial congestion level and the cost variable. This way, the comparability issue can be constrained.
- Another drawback is the issue of variety on complexity levels. In the case that the complexity levels of real-life congestion charge implementations are not very different from each other, we end up with too little observations. This will make it harder to determine the relationship between effectiveness and complexity level and we might end up with high standard errors.
- Limiting the number of investigated implementations to five causes too little observations. However, since there are no detailed and reliable data for other implementations, we have to accept the risk.
- Four of the five cities are in Europe and one is in Asia. Cultural differences can cause unexpected variances. This also threatens the generic nature of the research. This research is intended to create a reference that can be used generically by any congestion charge implementation in any

part of the world; however, the European majority in the observation can cause this research to be more Europe centered.

1.3. Quantification of Complexity Levels in Existing Congestion Charging Plans

1.3.1. Case of Stockholm

1.3.1.1. Definition of the Congestion Charge

Congestion charges in Stockholm were implemented after a seven-month trial in 2006. The trial started at the beginning of January, lasted until the end of July and was permanently implemented in 2007 (Schuitema et al., 2010). The start of the trial is taken as the basis of the implementation charge, since most of literature takes the beginning of the trial as the start date of congestion charge implementations in Stockholm. The congestion charge is described as the following:

"The fee for passing a control point was SEK 10, 15, or 20, respectively (corresponding to Euro 1.1, 1.6, and 2.2, respectively) depending on the time of day. No fees were levied in evenings, nights, Saturdays and Sundays, public holidays or a day before such a holiday. Various exemptions (for e.g. taxis, buses, eco-fuel cars and for bypass traffic from and to the island of Lidingö) made nearly 30% of all car passages free-of-charge. Equal fees were charged in both directions. The total daily payment of a vehicle was limited to SEK 60. One route (the Essinge bypass) was open free-of-charge for north-south or vice versa bypass through the toll zone." (Eliasson, Hultkrantz, Nerhagen, & Rosqvist, 2009).

The Swedish Transport Agency also includes following exemptions: emergency vehicles, EC mobile cranes, motorbikes and mopeds are also exempt from the charge (The Swedish Transport Agency, 2016). The agency also does not differentiate between the types of vehicles that need to pay the charges. The Swedish Transport Agency also states that the vehicles are identified by cameras and the payment slip is sent to the owner (The Swedish Transport Agency, 2016). Sweden uses ANPR (Automatic Number Plate Recognition) system, and IVUs (in-vehicle units) are not needed for vehicles. This means that there is no immediate method of payment, such as cash or credit card; instead the payment is due later. The agency states that the payment slip per say for Month 1, will be sent out at the end of Month 2, and the payment must be made before the end of Month 3, if the payment is not made by then, an additional fee of 500 SEK is charged (The Swedish Transport Agency, 2016). Eliasson et al. (2009) also state that the charges were imposed on vehicles passing a cordon around the inner city of Stockholm, meaning that the charge is applied on one area only.

The time intervals in which the charge differentiates is given in Table 32.

Table 32: Congestion Charge Differentiation Over the Day in Stockholm (Schuitema et al., 2010)

Time of Day		Charge
From	**Till**	
06.30	06.59	10 SEK
07.00	07.29	15 SEK
07.30	08.29	20 SEK
08.30	08.59	15 SEK
09.00	15.29	10 SEK

15.30	15.59	15 SEK
16.00	17.29	20 SEK
17.30	17.59	15 SEK
18.00	18.29	10 SEK
18.30	06.29	0 SEK

1.3.1.2. Complexity of the Congestion Charge

Based on the definition of the congestion charge, the following dimensions, levels, exemptions or discounts are identified.

Table 33: Complexity of the Stockholm Congestion Charge

Dimension	Explanation	Number of Levels
Time	There are 10 time intervals per day.	2
Cost	The charges applied are either 10 SEK, 15 SEK or 20 SEK.	2
Location	Charges apply only in one area.	1
Type of Vehicle	There is no differentiation between type of vehicles except the ones in the exemptions.	1
Method of Payment	There is no immediate method of payment.	-
Date of Payment	Payment must be made later, within one month after the payment slip for that month is delivered. There are no different payment schemes, e.g. paying for 3 months at once, or paying yearly etc.	1
Exemptions / Discounts		
Day exemptions: No charges on Saturdays, Sundays, public holidays or a day before such holiday. Vehicle exemptions: Taxis, buses, eco-fuel cars, emergency vehicles, EC mobile cranes, motorbikes and mopeds are exempt. Road exemptions: Essinge bypass and the bypass traffic from and to the island of Lidingö are exempt. There are 3 categories of exemptions in total. There are no discounts.		3
Total number of levels		**10**

In Stockholm congestion charge implementation, the total number of charge levels to which a given user might be subject to is 10; therefore, the complexity of this congestion charge can be identified as level 10 complexity.

1.3.1.3. Effectiveness: Reduction in Congestion

In regard to immediate effects of the implementation, Eliasson et al. (2009) state that the average reduction in traffic volume during charging hours, compared to the 12 month before, stabilized after the first month at around 22%. This can be seen in Figure 22. (Note that the trial period ended at the end of July until being permanently implemented in 2007, hence the difference in the months of August through December in Figure 22.)

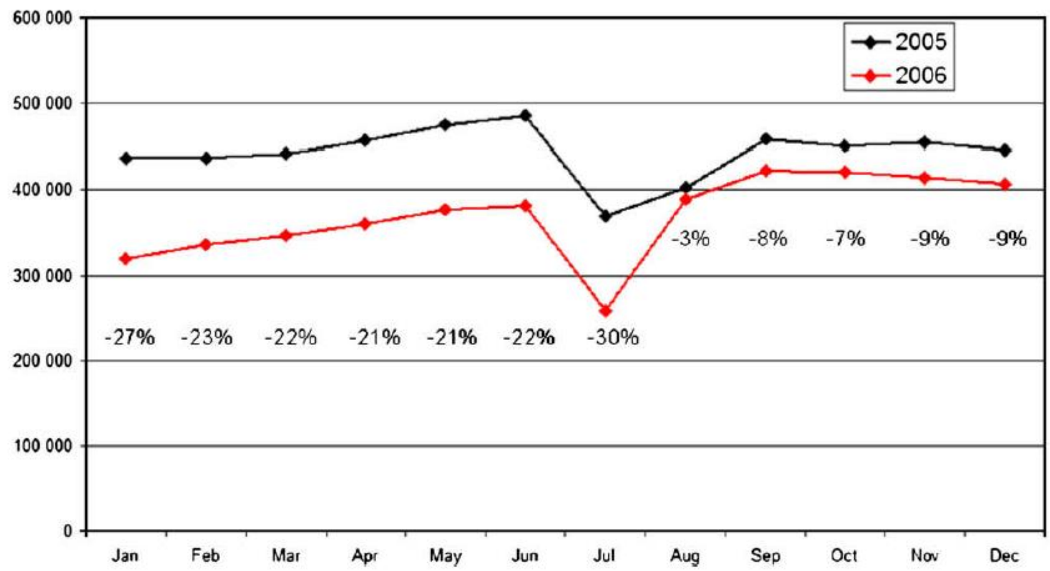

Figure 22: The number of vehicles passing across the congestion zone during day-time (6.00–19.00 weekdays). The charges were in place weekdays 6.30–18.30. (Eliasson et al., 2009)

Based on the information given above, the immediate effectiveness of Stockholm Congestion Charge is set to 22%.

1.3.1.4. Initial Congestion Level

As mentioned under research design choices, initial congestion level in this research is measured as the traffic volume passing through the congestion zone within charging hours per day, per kilometer square in the 12 months prior to implementation. Eliasson et al. (2009) state that the area of the charging zone in Stockholm is around 30 km^2. According to Eliasson's another paper in 2014, the rough average estimate of traffic volumes across the congestion zone within charging hours per day in 2005 which is 12 months prior to the implementation is 455,000 vehicles (Eliasson, 2014). Therefore, per kilometer square, the traffic volume is set to 15,167 vehicles.

1.3.1.5. The Cost Variable: Maximum Charge per Day per Vehicle as Percentage of GDP per Capita

Maximum charge per day per vehicle is limited to 60 SEK (Schuitema et al., 2010). Taking the first day of implementation as the currency rate, In January 1st, 2006, 1 SEK was 0.126 USD; therefore 60 SEK was approximately 7.55 USD (Trading Economics, 2017). According to the data of the World Bank, in the year 2006, average GDP per capita of Sweden was 46,256.16 USD (The World Bank, 2017c). The maximum charge per day per vehicle equals approximately to 0.016% of the GDP per capita of Sweden. Therefore, the value set for the cost variable is 0.016%.

1.3.2. Case of Gothenburg

1.3.2.1. Definition of the Congestion Charge

Congestion charging implementation resembles Stockholm case since it was built based on results from Stockholm implementation. Gothenburg congestion charges were implemented in the beginning of January 2013 (Börjesson & Kristoffersson, 2015).

The fee for passing a control point was either 8 SEK, 13 SEK or 18 SEK depending on the time of the day. The fees are not levied in Saturdays, Sundays, public holidays and the day before public holidays, and also the whole month of July (Transport Department of Hong Kong, 2015). Diplomatic vehicles, military vehicles, buses, emergency vehicles, EC mobile cranes, motorbikes and mopeds are also exempt from the charge (The Swedish Transport Agency, 2016). Maximum charge per day per vehicle is limited to 60 SEK (Börjesson & Kristoffersson, 2015). Similar to Stockholm case, The Swedish Transport Agency states that a fee of 500 SEK is applied if the payment is late. The method of payment and the date of payment are exactly the same as in Stockholm case. The fees are levied in both directions. There is an additional multi-passage rule: "if the zone is passed more than once within 60 min, only the highest charge has to be paid." (Börjesson & Kristoffersson, 2015). The charge is applied to one area only.

The time intervals in which the charge differentiates is given in Table 34.

Table 34: Congestion Charge Differentiation Over the Day in Gothenburg (Börjesson & Kristoffersson, 2015)

Time of Day		Charge
From	**Till**	
06.00	06.29	8 SEK
06.30	06.59	13 SEK
07.00	07.59	18 SEK
08.00	08.29	13 SEK
08.30	14.59	8 SEK
15.00	15.29	13 SEK
15.30	16.59	18 SEK
17.00	17.59	13 SEK
18.00	18.29	8 SEK
18.30	05.59	0 SEK

1.3.2.2. Complexity of the Congestion Charge

Based on the definition of the congestion charge, the following dimensions, levels, exemptions or discounts are identified.

Table 35: Complexity of the Gothenburg Congestion Charge

Dimensions	Explanation	Number of Levels
Time	There are 10 time intervals per day.	2
Cost	The charges applied are either 8 SEK, 13 SEK or 18 SEK.	2
Location	Charges apply only in one area.	1
Type of Vehicle	There is no differentiation between type of vehicles except the ones in the exemptions.	1
Method of Payment	There is no immediate method of payment.	-
Date of Payment	Payment must be made later, within one month after the payment slip for that month is delivered. There are	1

	no different payment schemes, e.g. paying for 3 months at once, or paying yearly etc.	
Exemptions / Discounts		
Day exemptions: No charges on Saturdays, Sundays, public holidays or a day before such holiday and in July. Vehicle exemptions: Diplomatic vehicles, military vehicles, buses, emergency vehicles, EC mobile cranes, motorbikes and mopeds are exempt. There are 2 categories of exemptions in total. There is one category of discounts. Frequency discounts: Multi-passage rule.		3
Total number of levels		**10**

In Gothenburg congestion charge implementation, the total number of charge levels to which a given user might be subject to is 10; therefore, the complexity of this congestion charge can be identified as level 10 complexity.

1.3.2.3. Effectiveness: Reduction in Congestion

In regard to the immediate effect of the congestion charge, Börjesson and Kristoffersson (2015) state that the average reduction in traffic volume during charging hours across the zone stabilized at 12% after 8 months. This can be seen in Figure 23. (Note that in the month of July, charges do not apply.)

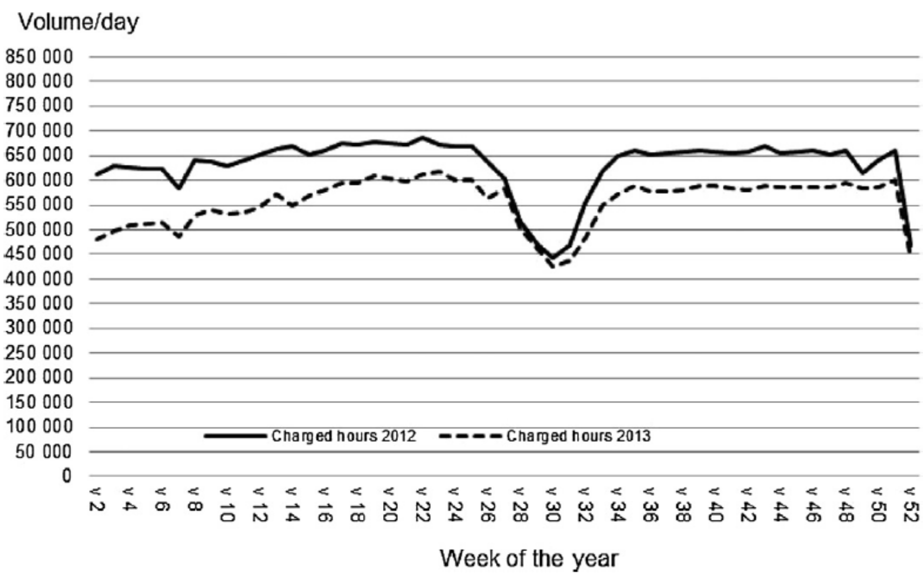

Figure 23: The number of vehicles passing the cordon during charged hours (weekdays 6:00–18:30) with and without congestion charging (Borjesson, Kristofferson, 2015)

Based on the information given above, the immediate effectiveness of Gothenburg Congestion Charge is set to 12%.

1.3.2.4. Initial Congestion Level

Area of the congestion charging zone in Gothenburg is roughly 12 km^2 (ERP). According to Börjesson and Kristoffersson (2015) the rough estimate of average traffic volumes within charging hours across the congestion zone per day in 2012 which is 12 months prior to implementation is 620,000 vehicles. Therefore, per kilometer square, the traffic volume is set to 51,667 vehicles.

1.3.2.5. The Cost Variable: Maximum Charge per Day per Vehicle as Percentage of GDP per Capita

Maximum charge per vehicle per day is limited to 60 SEK (Börjesson & Kristoffersson, 2015). On the first day of the implementation, on January 1st, 2013, 1 SEK was 0.154 USD; therefore 60 SEK was approximately 9.26 USD (Trading Economics, 2017). According to the data of the World Bank, in the year 2013, average GDP per capita of Sweden was 60,430.22 USD (The World Bank, 2017c). The maximum charge per day per vehicle equals approximately to 0.015% of the GDP per capita of Sweden. Therefore, the value set for the cost variable is 0.015%.

1.3.3. Case of London

1.3.3.1. Definition of the Congestion Charge

Congestion charges in London were implemented on February 17th, 2003. The charge applies from Monday to Friday, from 07.00 to 18.30 hours, excluding public holidays in one area (Santos, 2005). Compared to Stockholm and Gothenburg, the charge in London does not differentiate according to the time of day. "The charge is 5 GBP per day for all vehicles and charging times." (Santos, 2005). London also uses the same ANPR technology to identify vehicles as Stockholm and Gothenburg, so in-vehicle units are not needed. The payment needs to be done only once regardless of how many times user drives in and out of the zone within the day (Transport for London, 2017). Therefore, the maximum charge per day is also 5 GBP. In terms of date of payment, the charge can be paid in advance or on the day until 22.00. Late payment is available between 22.00 and midnight, but in that case the charge increases up to 10 GBP. In terms of the method of payment, the payment can be made via retail (e.g. shops, gas stations etc.), call center, internet and by post. If the payment is not done within the day, a penalty of 100 GBP is issued. If the penalty is paid within 14 days, it is reduced to 50 GBP, if not paid within 28 days, it is increased to 150 GBP (Santos, 2005).

Exemptions and discounts are various, and apply to the following: Two-wheeled motorbikes, mopeds, emergency service vehicles, national health service vehicles, vehicles with 'disabled' taxation class, taxi and private hire vehicles, buses, armed force vehicles, operational vehicles, vehicles used by Her Majesty's Coastguard and Port Authorities and vehicles of Royal Park Agency are exempt from the charges. Residents living inside the zone has 90% discount; blue badge holders (handicapped permit), breakdown vehicles, vehicles with nine or more seats, cars or vans with ultra-low emission, motor tricycles and roadside recovery vehicles receive 100% discount with one time registration fee (Transport Department of Hong Kong, 2015).

1.3.3.2. Complexity of the Congestion Charge

Based on the definition of the congestion charge, the following dimensions, levels, exemptions or discounts are identified.

Table 36: Complexity of the London Congestion Charge

Dimensions	Explanation	Number of Levels
Time	There are 2 time intervals. 07.00 to 18.30 and vice versa 18.30 to 07.00. (Daily Charge)	1
Cost	The charge applied is fixed for 5 GBP during all charging hours.	1
Location	Charges apply only in one area.	1
Type of Vehicle	There is no differentiation between type of vehicles except the ones in the exemptions.	1
Method of Payment	There are 4 methods of payment: by retail, call center, internet and post.	2
Date of Payment	Payment can be in advance, during, or between 22.00 - 24.00 of the charging day.	2
Exemptions / Discounts		
There are 4 categories of exemptions / discounts. Day exemptions: Saturdays, Sundays and public holidays. Vehicle exemptions and discounts: exemptions for motorbikes, mopeds, emergency vehicles etc. and discounts for cars or vans with ultra-low emission, motor tricycles etc. Residence discounts: Apply to residents living inside the zone. Health discounts: blue badge holders (handicapped permit). Vehicle discounts:		4
Total number of levels		**12**

In London congestion charge implementation, the total number of charge levels to which a given user might be subject to is 12; therefore, the complexity of this congestion charge can be identified as level 12 complexity.

1.3.3.3. Effectiveness: Reduction in Congestion

In regard to the immediate effect of the congestion charge, Transport for London (2007) state that there was an average of 14% reduction in the overall traffic volume entering the charging zone during charging hours after one year of implementation. Therefore, the effectiveness of the London Congestion Charge is set to 14%.

1.3.3.4. Initial Congestion Level

Area of the congestion zone in London is roughly 22 km^2 (Santos, 2005). Transport for London (2004) states that the average traffic volume passing through the congestion zone within charging hours per day in 2002 (one year prior to implementation) is 376,000. Therefore, per kilometer square the traffic volume is set to 17,090 vehicles.

1.3.3.5. The Cost Variable: Maximum Charge per Day per Vehicle as Percentage of GDP per Capita

The maximum charge per day per vehicle is 5 GBP. The first day of the implementation, on February 17th, 2003, 1 GBP was 1.596 USD, thus 5 GBP was approximately 7.98 USD (Trading Economics, 2017). According to the data of the World Bank, in the year 2003, average GDP per capita of United Kingdom was 32,586.64 USD (The World Bank, 2017d). The maximum charge per day per vehicle equals approximately to 0.024% of the GDP per capita of UK. Therefore, the value for the cost variable is set to 0.024%.

1.3.4. Case of Milan

1.3.4.1. Definition of the Congestion Charge

Congestion charges in Milan were implemented on January 1st, 2008. The implementation was called Ecopass. The charge was a daily charge, levied between 07.30 to 19.30 from Monday to Friday. There is no charge on Saturdays, Sundays and public holidays. The charges differentiated proportional to vehicles' PM10 tail emissions (Croci, 2016). Based on their emissions, five categories of vehicles were described. Vehicle categories and the daily charge applied to them are given below in Table 37.

Table 37: Class Vehicle Categories and Charges (Croci, 2016)

Class	Category of Vehicle	Daily Charge (Euros)	PM10 Emission Factors
Class 1	Low emission vehicles	Free	-
Class 2	Petrol Euro 3+, Diesel Euro 3+, Diesel Euro 4	Free	≤ 10 mg/km
Class 3	Petrol Euro 1 and Euro 2	2 EUR	≤ 10 mg/km
Class 4	Petrol Euro 0, Diesel Euro 1, 2, 3, Diesel Commercial Euro 4	5 EUR	> 10 mg/km ≤ 100 mg/km
Class 5	Diesel Euro 0, Diesel Commercial Euro 0, 1, 2	10 EUR	> 100 mg/km

The charges are applied within one are only. The maximum charge is 10 EUR and similarly to Stockholm, Gothenburg and London charges, ANPR technology was used to identify the vehicles (Danielis, Rotaris, Marcucci, & Massiani, 2012). There are three methods of payments by internet, phone or at the bank (Gibson & Carnovale, 2015). Public transportation vehicles, taxis, disabled vehicles and motorcycles are exempt from the charge. 90% discounts are given to residents if they bought yearly permits. Also, several discount tickets were available e.g. first 50 entries with 50% discount, successive 50 entries with 40% discount and no discounts after 100 entries (Croci, 2016). A basic fine of 70 EUR was set, which could rise to 275 EUR if not paid within given time (Gibson & Carnovale, 2015). Users can enter and leave the zone as many times as they wish, but pay the daily charge only once in a day. The payment can be made in advance, during the day or until midnight of the next day (Corriere Milano, 2008).

1.3.4.2. Complexity of the Congestion Charge

Based on the definition of the congestion charge, the following dimensions, levels, exemptions or discounts are identified.

Table 38: Complexity of the Milan Congestion Charge

Dimensions	Explanation	Number of Levels
Time	There are 2 time intervals. 07.30 to 19.30 and vice versa 19.30 to 07.30. (Daily Charge)	1
Cost	The charges applied are either 2 EUR, 5 EUR or 10 EUR.	2
Location	Charges apply only in one area.	1
Type of Vehicle	There are five categories of vehicles according to which the charge differentiates.	2

Method of Payment	Three methods of payment: by internet, phone or bank.	2
Date of Payment	Payment can be made in advance, during the day or the next day.	2
Exemptions / Discounts		
There are 4 categories of exemptions / discounts. Day exemptions: Saturdays, Sundays and public holidays. Vehicle exemptions: taxis, motorcycles etc. Residence discounts and ticket discounts.		4
Total number of levels		**14**

In Milan congestion charge implementation, the total number of charge levels to which a given user might be subject to is 14; therefore, the complexity of this congestion charge can be identified as level 14 complexity.

1.3.4.3. Effectiveness: Reduction in Congestion

In regard to the immediate effect of the congestion charge, Percoco (2014) states that the average reduction in the overall traffic volume entering the charging zone, during charging hours, after the first 11 months of implementation is 12%. Therefore, the effectiveness of the Milan Congestion Charge is set to 12%.

1.3.4.4. Initial Congestion Level

Area of the congestion charging zone in Milan is roughly 8 km2 (Croci, 2016). Percoco (2014) states that one year prior to the implementation of the congestion charge average traffic volume passing through the congestion zone within charging hours per day was 98,000. Therefore, per kilometer square the traffic volume is set to 12,250 vehicles.

1.3.4.5. The Cost Variable: Maximum Charge per Day per Vehicle as Percentage of GDP per Capita

The maximum charge per day per vehicle is 10 EUR. The first day of implementation, on January 1st, 2008, 1 EUR was 1.462 USD, thus 10 EUR was approximately 14.62 USD (Trading Economics, 2017). According to the data of the World Bank, in the year 2008, average GDP per capita of Italy was 40,661.17 USD (The World Bank, 2017a). The maximum charge per day per vehicle equals approximately to 0.036% of the GDP per capita of Italy. Therefore, the value for the cost variable is set to 0.036%.

1.3.5. Case of Singapore

1.3.5.1. Definition of the Congestion Charge

Congestion charging in Singapore was implemented in September 1st, 1998 (Olszewski & Xie, 2005). The charging scheme is called electronic road pricing (ERP), and it was implemented on top of a previous system called area licensing scheme (ALS). ALS was not exactly a congestion charging scheme, instead it restricted access to certain areas through the purchase of supplementary licenses (Goh, 2002). The technology used in Singapore was different compared to Stockholm, Gothenburg, London and Milan. ERP system requires the installation of in-vehicle units (IUs). These IUs work with smartcards called CashCards. User loads the smartcard prior to journey and puts the smartcard into the IU while passing through an

ERP control point. The payment is deducted from the smartcard automatically at the control point. ERP control points use radio frequencies to contact the IUs in the vehicle. Photographs are only taken when a vehicle violates the system (Menon & Guttikunda, 2010). In case of violation, the registered person for the plate is asked to pay 10 SGD fee plus the ERP charge within 2 weeks of the violation; if the fees are not paid, the penalty is increased to 70 SGD to be paid in 28 days; if the fee is still unpaid after 28 days, it is taken to court (Santos, 2005).

The charging area is divided into central business districts, express ways and arterial roads. There are in total 12 different entry points in which the charges differentiate (Goh, 2002). The charges vary according to time of the day, location of entry and the vehicle type. The day is divided into 9 time intervals. The charges differ between 0.25 SGD and 2.50 SGD. Specifically the following charges are applicable: 0.25 SGD, 0.40 SGD, 0.50 SGD, 0.70 SGD, 0.75 SGD, 0.80 SGD. 1.00 SGD, 1.15 SGD, 1.25 SGD, 1.40 SGD, 1.50 SGD, 1.70 SGD, 1.90 SGD, 2.00 SGD, 2.50 SGD (Goh, 2002). The vehicles are divided into six categories: car (private/company), taxi, light goods vehicle, motorcycle, heavy goods vehicle / small bus and very heavy goods vehicle / big bus (Seik, 2000). This categorization is made based on the passenger car unit (PCU) ratings of the vehicles.

There are very few exemptions in Singapore; only the emergency vehicles are exempt from the charge. There are no discounts. An example of charge differentiation is given below in Table 39 for Nicoll Highway which is one of the 12 different entry points / roads in the ERP system.

Table 39: Charge Variance on Nicoll Highway in Singapore (Goh, 2002)

Time	Vehicle Categories					
	1	2	3	4	5	6
07.30 – 08.00	0.50	0.50	0.80	1.00	0.70	1.00
08.00 – 08.30	1.25	1.25	1.90	2.50	1.70	2.50
08.30 – 09.00	1.25	1.25	1.90	2.50	1.70	2.50
09.00 – 09.30	1.00	1.00	1.50	2.00	1.40	2.00
09.30 – 17.30	0.50	0.50	0.80	1.00	0.70	1.00
17.30 – 18.00	0.75	0.75	1.15	1.50	1.00	1.50
18.00 – 18.30	1.00	1.00	1.50	2.00	1.40	2.00
18.30 – 19 00	0.50	0.50	0.80	1.00	0.70	1.00
19.00 – 07.30	0.00	0.00	0.00	0.00	0.00	0.00
1: Motorcycles, **2**: Light good vehicles, **3**: Heavy good vehicles / small buses, **4**: Very heavy goods vehicles / big buses, **5**: Taxis, **6**: Passenger cars						

Differently than previously analyzed congestion charging implementations, ERP system in Singapore does not have a maximum charge per vehicle per day; instead, the users are charged per crossing (Santos, 2005). This provides a challenge for the calculation of the cost variable to be used in the regression analysis. This issue is addressed in the following way: Three months after the implementation, average daily toll collected from the ERP system was 113,000 SGD, during the same period, average daily traffic volume was 211,000 vehicles (Seik, 2000). This suggests that the average charge per vehicle was roughly 0.53 SGD. This number suggests that the average charge per day is within the charge variance (0.25 SGD, 2.50 SGD). Based on this, the upper limit of the charge variance is taken as the maximum charge per vehicle per day to be used in calculating the cost variable.

1.3.5.2. Complexity of the Congestion Charge

Based on the definition of the congestion charge, the following dimensions, levels, exemptions or discounts are identified.

Table 40: Complexity of the Singapore Congestion Charge

Dimensions	Explanation	Number of Levels
Time	There are 9 time intervals.	2
Cost	There are 15 different charges in total which are applied to different vehicle types at different hours at different locations.	2
Location	There are 12 different highways / roads / entry points according to which the charge differentiates.	2
Type of Vehicle	There are 6 types of vehicles.	2
Method of Payment	There is only one method of payment: by smartcard.	1
Date of Payment	The payment is immediate.	1
Exemptions / Discounts		
There is only one category of exemption / discounts. Vehicle exemptions: for emergency vehicles only.		1
Total number of levels		**11**

In Singapore congestion charge implementation, the total number of charge levels to which a given user might be subject to is 11; therefore, the complexity of this congestion charge can be identified as level 11 complexity.

1.3.5.3. Effectiveness: Reduction in Congestion

In regard to the immediate effect of the congestion charge, Santos (2005) states that the average reduction in the overall traffic volume entering the charging zone, during charging hours, 1 year after the introduction is 16%. Therefore, the effectiveness of the Singapore Congestion Charge is set to 16%.

1.3.5.4. Initial Congestion Level

Area of the congestion charging zone in Singapore is roughly 8km^2 (Transport Department of Hong Kong, 2015). Prior to implementation, average traffic volume passing through the congestion zone within charging hours per day was 271,000 (Seik, 2000). Therefore, per kilometer square the traffic volume is set to 33,875 vehicles.

1.3.5.5. The Cost Variable: Maximum Charge per Day per Vehicle as Percentage of GDP per Capita

The maximum charge per day per vehicle is 2.50 SGD. The first day of implementation, on September 1st, 1998, 1 SGD was 0.58 USD, thus 2.50 SGD was approximately 1.45 USD (Trading Economics, 2017). According to the data of the World Bank, in the year 1998, average GDP per capita of Singapore was 21,824.09 USD (The World Bank, 2017b). The maximum charge per day per vehicle equals approximately to 0.0007% of the GDP per capita of Singapore. Therefore, the value for the cost variable is set to 0.007%.

1.4. Regression Analysis

For the regression analysis, there are only five observations. It is not possible to estimate a significant relationship between any of the variables with just five observations. Note that the influence of complexity on effectiveness in congestion charging implementations is extremely underrepresented in literature. There is no sound proof of whether increased complexity causes status quo effect or ambiguity avoidance. However, an interpretation of the data can be made and we can have a basic understanding of a possible relationship. The findings from the case studies are given below in Table 41.

Table 41: Overall Comparison of Congestion Charging Case Studies

City	**Complexity Level**	**Effectiveness** (Immediate Percentage Reduction in Congestion)	**Initial Congestion Level** (vehicles/km^2)	**The Cost Variable** (Maximum Charge per Day per Vehicle as Percentage of GDP per Capita)
Stockholm	10	22	15,167	0.016%
Gothenburg	10	12	51,667	0.015%
London	12	14	17,090	0.025%
Milan	14	12	12,250	0.036%
Singapore	11	16	33,875	0.007%

If the number of observations were higher, a multiple regression analysis would prove useful, but since that is not the case, bilateral relationships were investigated. The significance level for all regression analyses were set to 0.05. Minitab determined a linear relationship in all cases, since a non-linear relationship would not be possible to estimate due to the few number of observations. First, the effectiveness levels of individual cases were adjusted with respect to their initial congestion level and the cost variable. In order to do this, relationship between the relationship between Effectiveness and Initial Congestion Level, and the relationship between Effectiveness and the Cost Variable were examined in Minitab. The results are given in Annex I, at the end of this chapter.

Regression for Effectiveness vs Initial Congestion Level: The results show that there is no statistically significant correlation between the two variables. Minitab determines a negative relationship. The results imply that as the initial congestion level increases, effectiveness decreases.

Regression for Effectiveness vs The Cost Variable: The results show that there is no statistically significant relationship between the two variables. Minitab determines a negative relationship. As the cost variable increases, effectiveness decreases. This implies that if the charges are low, the reduction in congestion is more effective.

Effectiveness values in each case were adjusted according to these findings in order to remove the influences of initial congestion level and the cost variable and thus to be able to compare complexity levels with less outside influences. This is done in the following way. Initial congestion levels for each case was pushed or pulled to the average level of the five cases. The equation for the relationship between effectiveness (E) and initial congestion level (ICL) is:

$$E = 17.43 - 0.000086\, ICL$$

The equation suggests that a single unit increase in the initial congestion level decreases the effectiveness level by 0.000086. (Note that effectiveness level is on a scale of 0 to 100). The average initial congestion level is 26,009.8 vehicles/ km^2. Let's take Stockholm as an example. Stockholm's initial congestion level is 15,167 vehicles/ km^2. The difference between the average initial congestion level and Stockholm's initial congestion level is 10,842.8. If Stockholm's initial congestion level was pushed towards the average initial congestion level -an increase of 10,842.8- this would result in 0.93 (0.000086 multiplied by 10,842.8) decrease in its effectiveness level. Therefore, adjusting the initial congestion level to average of the five cities, would hypothetically decrease Stockholm's effectiveness by 0.93. The same calculation is performed for all cities.

The equation for the relationship between effectiveness (E) and the cost variable (C) is:

$$E = 18.32 - 15805\ C$$

The cost variables for each city was pushed or pulled to the average of the five cities, and their effect on the effectiveness were calculated in the same manner described above for the initial congestion level. The adjustments are summarized below in Table 42.

Table 42: Adjustments to Effectiveness

City	Effectiveness	Influence on Effectiveness by the Adjustment of Initial Congestion Charge	Influence on Effectiveness by the Adjustment of the Cost Variable	Total Change in Effectiveness	Adjusted Effectiveness
Stockholm	22	-0.93	-0.55	-1.48	20.52
Gothenburg	12	2.21	-0.70	1.50	13.50
London	14	-0.77	0.75	-0.02	13.98
Milan	12	-1.18	2.57	1.38	13.38
Singapore	16	0.68	-2.07	-1.39	14.61

Once the adjusted effectiveness levels were set for each congestion charge implementation, the relationship between complexity and the adjusted effectiveness was examined in Minitab. The results are given in Annex I at the end of this chapter. A remark on why these adjustments were made: Since there are too few observations, it is not possible to estimate the influence of cost and initial congestion level in a more complicated manner; yet we can still account for some of the influence by looking at the bilateral relationship cost and initial congestion level has with effectiveness; and this is why these adjustments were performed.

Regression for Adjusted Effectiveness vs Complexity: The results show that there is no statistically significant correlation between the two variables. Minitab determines a negative relationship. The results imply that as the complexity increases effectiveness decreases. The equation for the relationship between effectiveness (E) and complexity level (CL) is:

$$E = 25.67 - 0.9185\ CL$$

Once the data is observed, the characteristics of the Swedish cities of Stockholm and Gothenburg are notable. These two cities have the same complexity level due to the fact that the Gothenburg implementation mostly copied the footsteps of the Stockholm implementation. Their cost variables are also very close to each other. However, there is a huge difference in their effectiveness and initial congestion levels. The effectiveness of Stockholm Congestion Charge Implementation is higher than anywhere else in the world; and the initial congestion level of Gothenburg is much higher than all other cities. In the regression graphs, their values stand as outliers, see Figure 24.

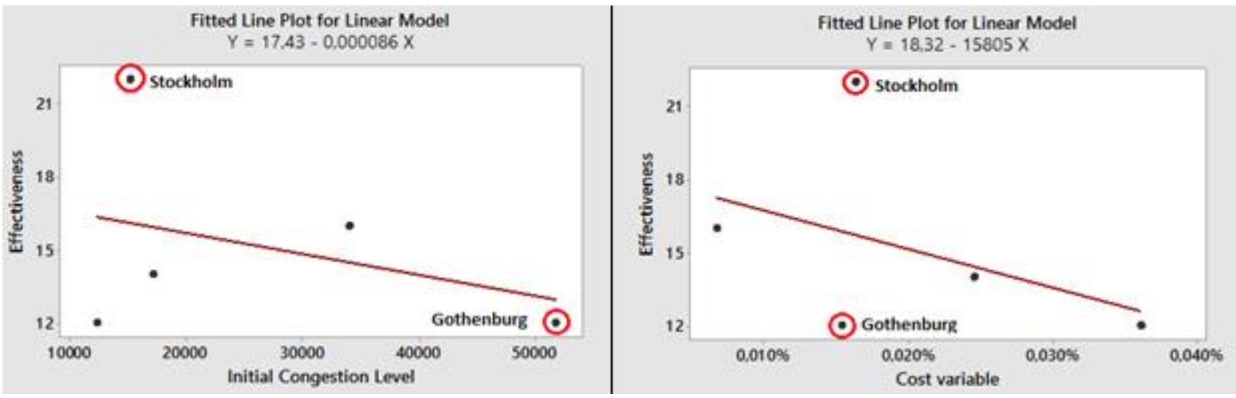

Figure 24: Outliers in Regression Graphs, E vs ICL and E vs C

There might be several reasons why Swedish cities provide outlying values compared to other cities. One possible reason might be that the policy objective might have had unexpectedly high impact on effectiveness. (Policy objective in Stockholm was to reduce congestion, whereas in Gothenburg, it was to reduce congestion and also gather revenues for public investments.) Another possible reason might be that the effectiveness of congestion charge implementations in Sweden might be highly influenced by politics. The actual reasons might be different; however, the nature of the data suggests that it is worthwhile to re-run the regression analysis excluding Stockholm and Gothenburg and compare the results.

Excluding the data from Stockholm and Gothenburg, the new relationships between effectiveness and initial congestion level and between effectiveness and the cost variable are given below in Figure 25.

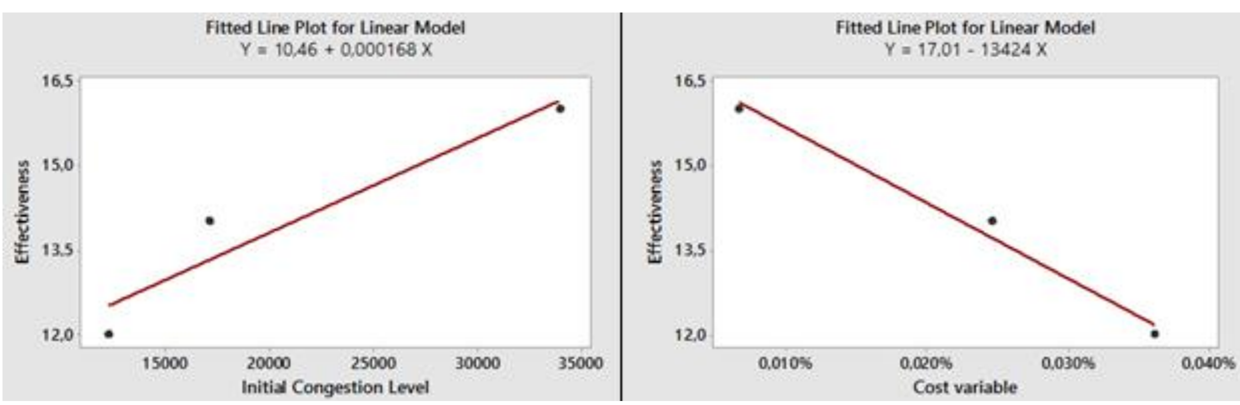

Figure 25: Relationships between Effectiveness – Initial Congestion, and Effectiveness – Cost, excl. Stockholm and Gothenburg

The effectiveness levels were adjusted excluding the data from Stockholm and Gothenburg. The adjustments are summarized below in Table 43. The relationship between effectiveness and complexity level excluding Swedish cities is given in Figure 26, in comparison to the not excluded version.

Table 43: Adjustment to Effectiveness Excluding Stockholm and Gothenburg

City	Effectiveness	Influence on Effectiveness by the Adjustment of Initial Congestion Charge	Influence on Effectiveness by the Adjustment of the Cost Variable	Total Change in Effectiveness	Adjusted Effectiveness
London	14	0.67	0.28	0.95	14.95
Milan	12	1.48	1.83	3.31	15.31
Singapore	16	-2.15	-2.11	-4.26	11.74

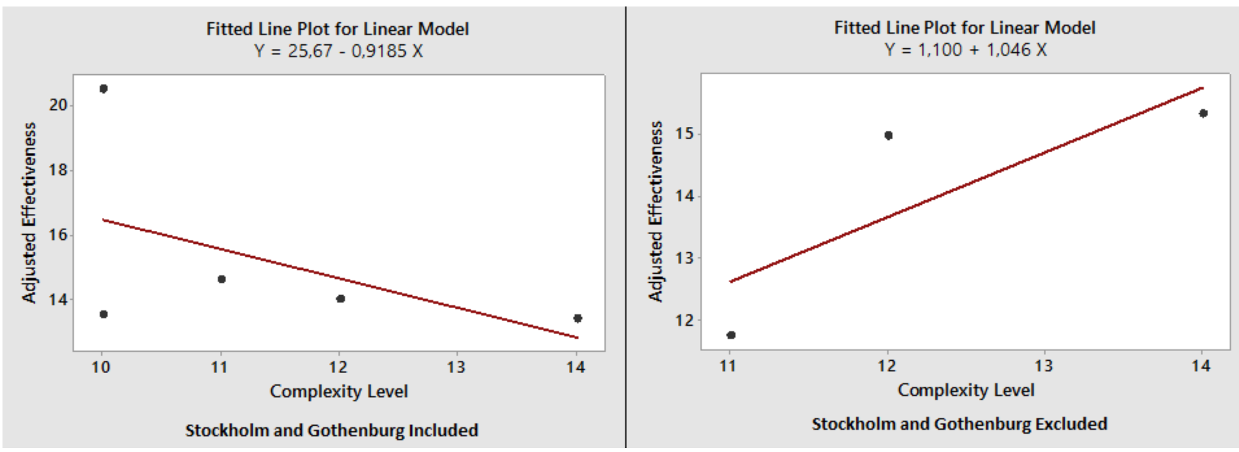

Figure 26: Relationship between Effectiveness and Complexity, including and excluding Swedish cities

The results of the regression analyses excluding Swedish cities are given in Annex II, at the end of this chapter. There was no statistically significant correlation between any variables (E vs ICL, E vs C and E vs CL) in any regression analyses. There were two main differences in results when including and excluding Swedish cities. First, the relationship between effectiveness and initial congestion level was reversed when the Swedish cities were excluded. Minitab determined a positive relationship. The results implied that the effectiveness increased as the initial congestion level increased. This falls in line with the expectations more, compared to the negative relationship which was the result when Swedish cities were included, because based on the literature review, initial congestion level was one of the most important factors influencing the effectiveness, and it was assumed that if the initial congestion level was higher, effectiveness would increase. Another difference is that the relationship between effectiveness and complexity level was also reversed. This results imply that as complexity level increases, effectiveness also increases. The regression equation for this positive result is:

$$E = 1.100 + 1.046\ CL$$

The discussion of these results is given in Chapter 5.

Annex I: Regression Analysis Results for Stockholm and Gothenburg Included

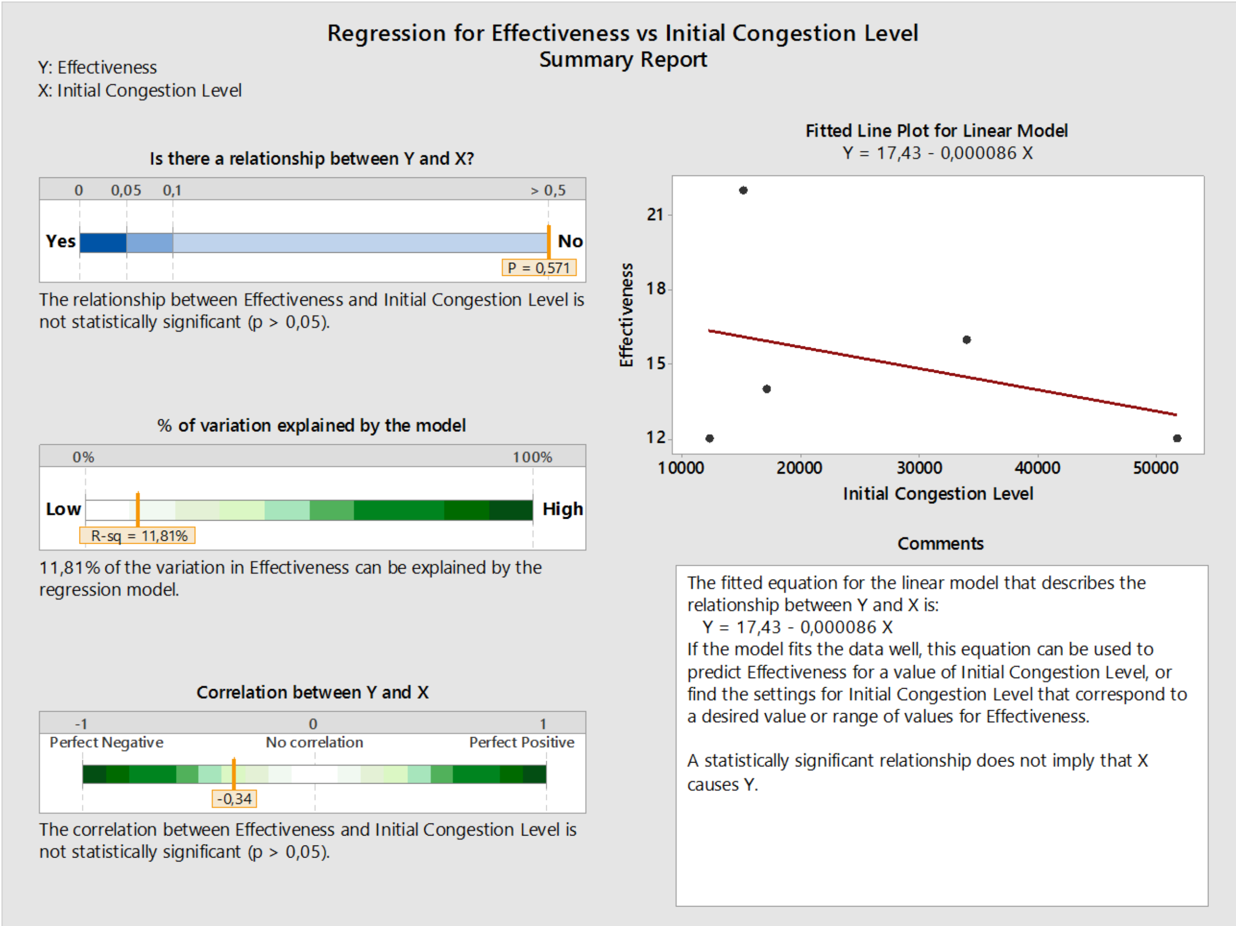

Figure 27: Regression for Effectiveness vs Initial Congestion Level

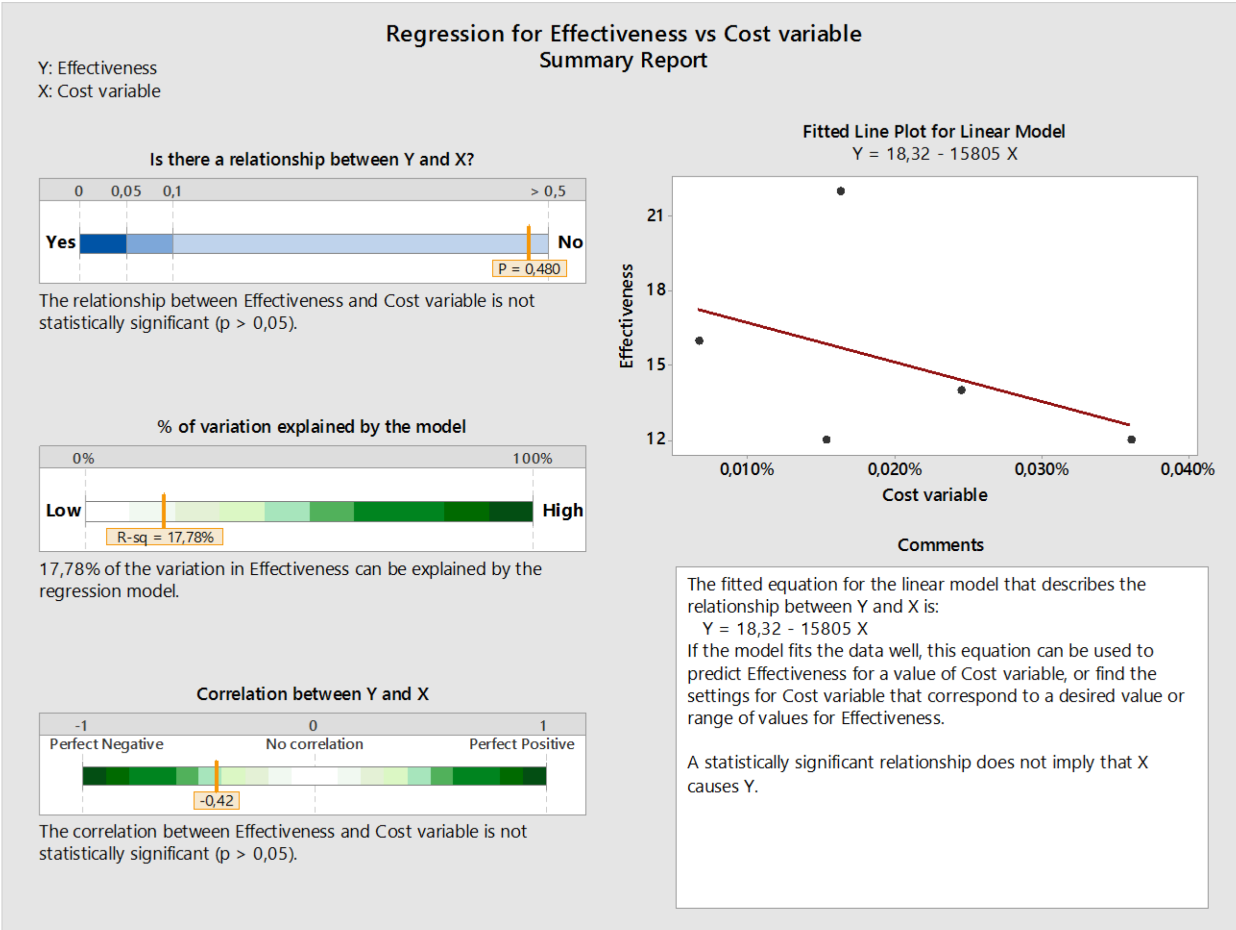

Figure 28: Regression for Effectiveness vs Cost Variable

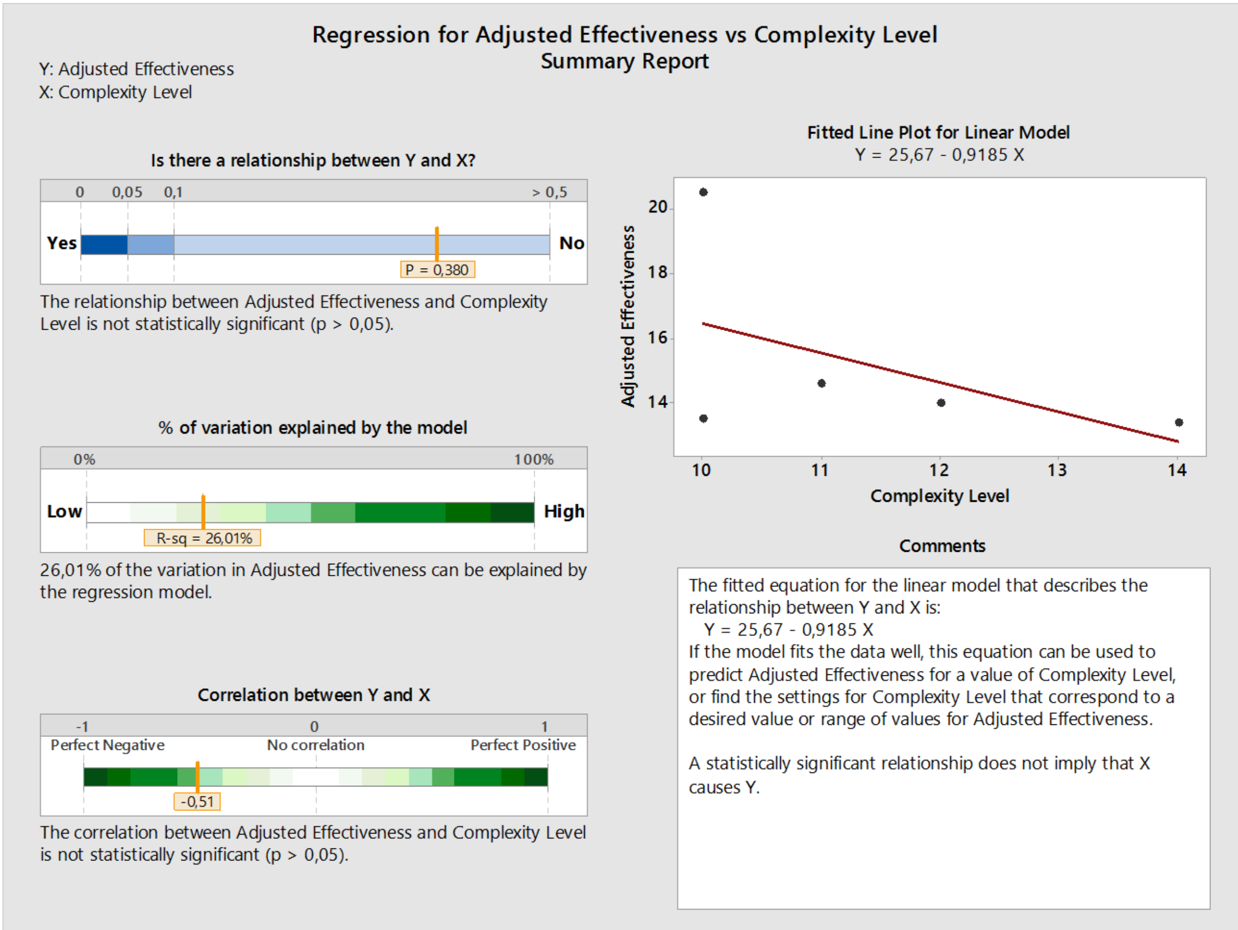

Figure 29: Regression for Adjusted Effectiveness vs Complexity Level

Annex II: Regression Analysis Results for Stockholm and Gothenburg Excluded

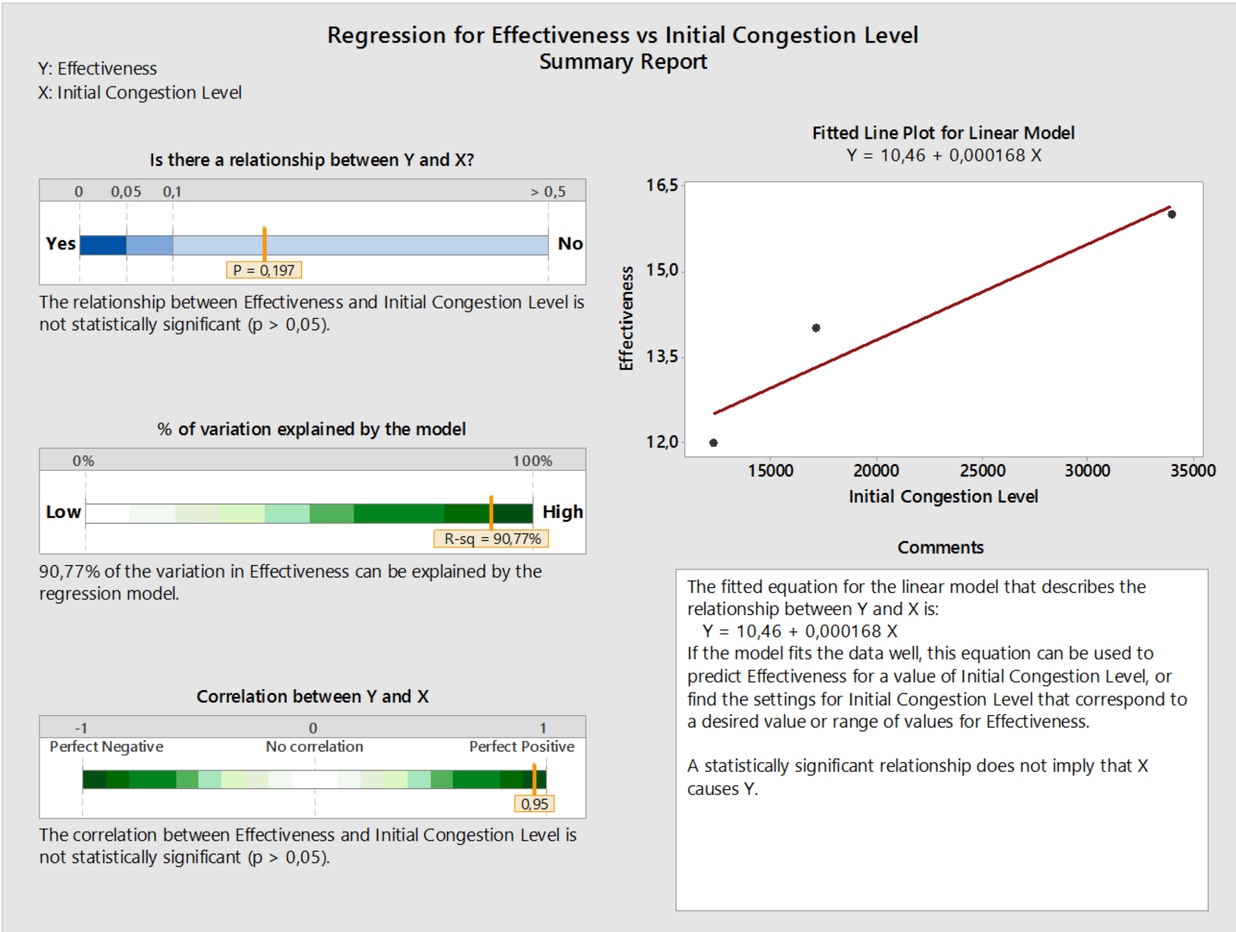

Figure 30: Regression for Effectiveness vs Initial Congestion Level

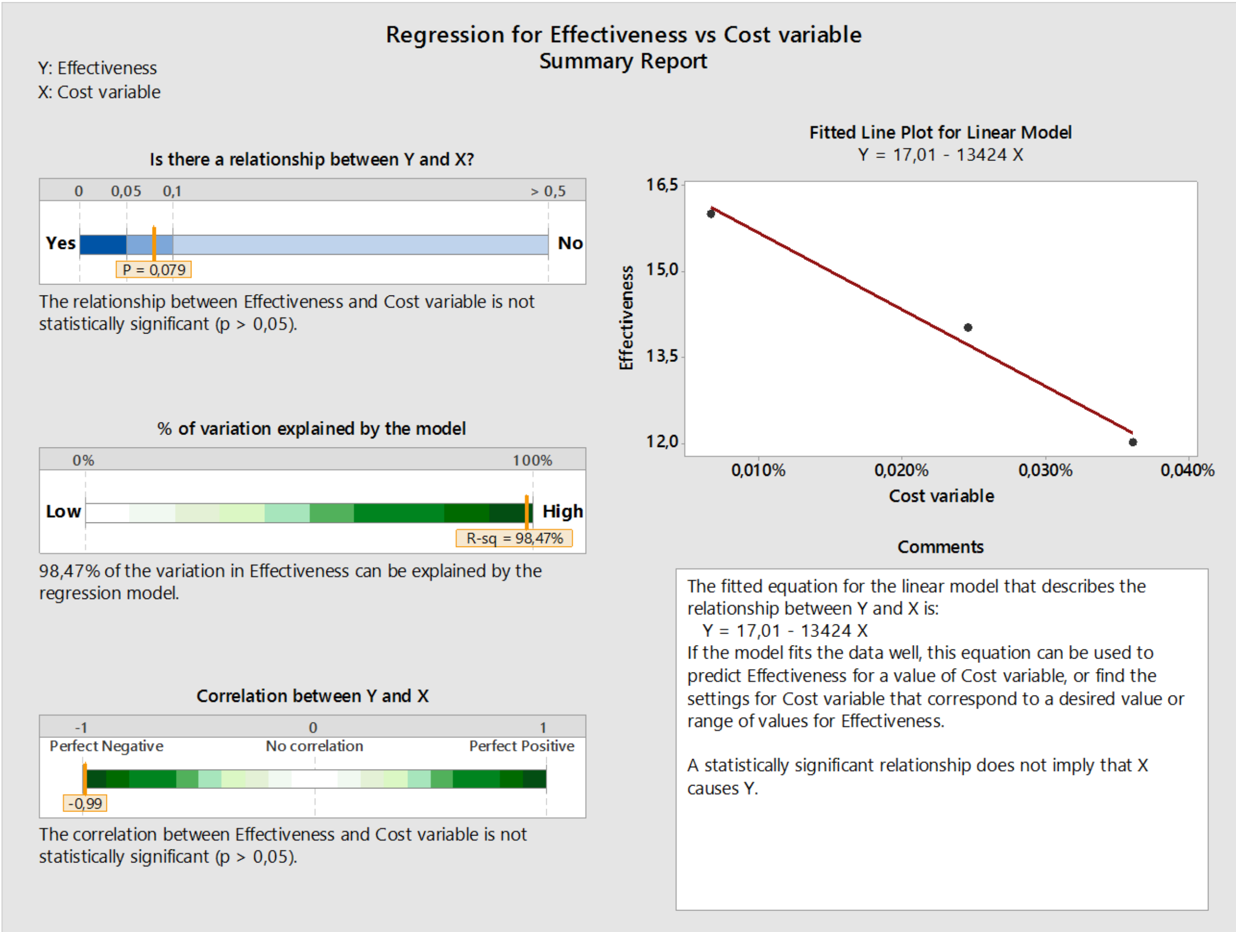

Figure 31: Regression for Effectiveness vs Cost Variable

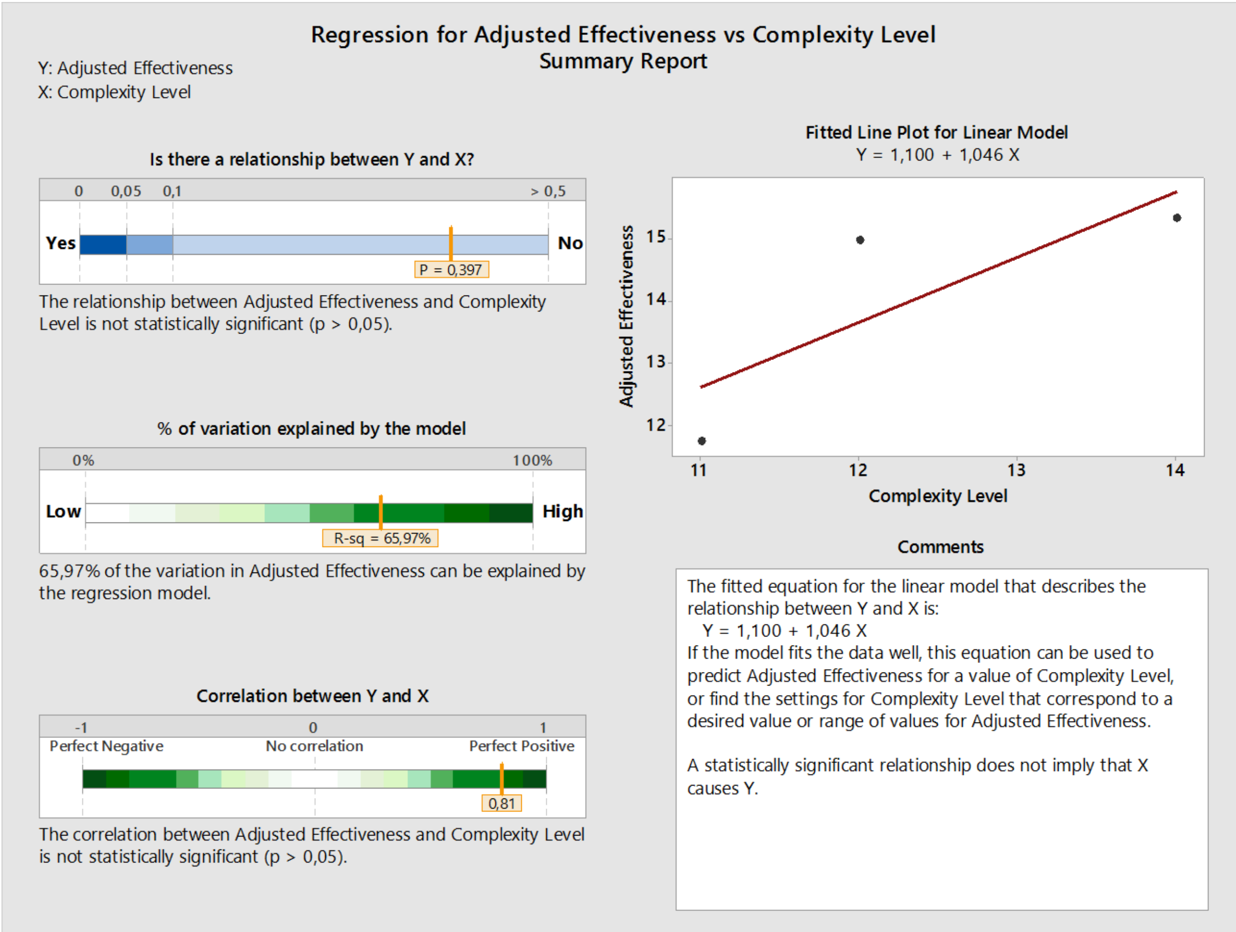

Figure 32: Regression for Adjusted Effectiveness vs Complexity Level

Appendix II

1.1. Text of the Pilot Survey (Including the Rating Experiment and the Stated Choice Experiment)

Public Opinion Survey Regarding Congestion Charging Implementations

Congestion charging refers to imposing a charge for vehicles driving in certain parts of a city in order to reduce traffic. Imagine that you are living in a city which is suffering from traffic congestion. There is a plan to implement congestion charges for a certain zone (or zones). Before the implementation of the charges, you are asked for your opinion in terms of the plan's acceptability to you.

In this part of the survey, you will be presented 8 different congestion charging plans and asked to rate them. Congestion charging plans presented in this survey has the following characteristics:

Dimensions of the Congestion Charge: Each congestion charge has either 5 or 6 dimensions. The following five dimensions are default: Time, Location, Cost, Type of Vehicle, Date of Payment. Some congestion charges also have Method of Payment as an additional dimension, thus totaling at 6 dimensions.

Variation within Dimensions: Each charging plan either belongs to Variation 1 or Variation 2.

Dimension	Variation 1	Variation 2
Time	Charge is a daily charge. 07.30 – 18.30	Charge varies within each hour.
Location	One area.	Multiple areas.
Cost	Fixed.	Varies depending on other factors.
Type of Vehicle	Same charge for all types of vehicles.	Different charges for different types of vehicles.
Date of Payment	During charging hours only.	Before, during or after the charging hours.
Method of Payment	One method only.	Multiple methods.

Exemptions / Discounts: Each congestion charge has a number of exemptions / discounts, ranging from 1 to 4.

PART 1/3

Please rate the following congestion charge schemes in terms of their acceptability to you on a scale of 0 to 5; 0 being not acceptable and 5 being fully acceptable.

Congestion Charging Plan No: 1

A proposed congestion charging plan in the city will have the following features:

Time	The charge will apply between 07.30 am and 18.30 pm. This time frame is divided into 9 time intervals and in each time frame the cost of the charge varies.
Location	Congestion charging will be applied in two areas covering 10 km^2 each within the city center.
Cost	The cost of the charge will vary depending on the area and the time of entry to the zone.
Type of Vehicle	The charges will also vary depending on the type of vehicles.
Date of Payment	The payment can be made in advance, during the charging hours once the vehicle enters the congestion zone or in a limited time frame afterwards.
Exemptions / Discounts	
(1) No charge is levied on Saturdays, Sundays and public holidays.	

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 2

A proposed congestion charging plan in the city will have the following features:

Time	The charge will apply between 07.30 am and 18.30 pm. This time frame is divided into 9 time intervals and in each time frame the cost of the charge varies.
Location	Congestion charging will be applied in two areas covering 10 km^2 each within the city center.
Cost	The cost of the charge will vary depending on the area and the time of entry to the zone.
Type of Vehicle	The charges will also vary depending on the type of vehicles.
Date of Payment	The payment can be made in advance, during the charging hours once the vehicle enters the congestion zone or in a limited time frame afterwards.
Method of Payment	The payments can be made by smartcards, by credit card, on the internet or by phone call. Smartcards are be provided to users before the implementation, users need to load money on their smartcards before entering the congestion zone if they choose to make the payment with this method.
Exemptions / Discounts	
(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge.	

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 3

A proposed congestion charging plan in the city will have the following features:

Time	The charge will apply between 07.30 am and 18.30 pm. Daily charge.
Location	Congestion charging will be applied in one area covering 20 km^2 within the city center.
Cost	The cost of the charge will be fixed for all charging hours.
Type of Vehicle	The charges are the same for all type of vehicles.
Date of Payment	The payment should be made during the charging hours once the vehicle enters the congestion zone.
Method of Payment	The payments can be made only by smartcards, which will be provided to users before the implementation. Users need to load money on their smartcards before entering the congestion zone.
Exemptions / Discounts	
(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge. **(3)** In addition, there will be discounts for people living inside the congestion zone. **(4)** There will also be discounts if you enter the congestion zone on certain roads.	

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 4

A proposed congestion charging plan in the city will have the following features:

Time	The charge will apply between 07.30 am and 18.30 pm. This time frame is divided into 9 time intervals and in each time frame the cost of the charge varies.
Location	Congestion charging will be applied in two areas covering 10 km^2 each within the city center.
Cost	The cost of the charge will vary depending on the area and the time of entry to the zone.
Type of Vehicle	The charges will also vary depending on the type of vehicles.
Date of Payment	The payment can be made in advance, during the charging hours once the vehicle enters the congestion zone or in a limited time frame afterwards.
Exemptions / Discounts	
(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge. **(3)** In addition, there will be discounts for people living inside the congestion zone.	

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 5

A proposed congestion charging plan in the city will have the following features:

Time	The charge will apply between 07.30 am and 18.30 pm. This time frame is divided into 9 time intervals and in each time frame the cost of the charge varies.
Location	Congestion charging will be applied in two areas covering 10 km^2 each within the city center.
Cost	The cost of the charge will vary depending on the area and the time of entry to the zone.
Type of Vehicle	The charges will also vary depending on the type of vehicles.
Date of Payment	The payment can be made in advance, during the charging hours once the vehicle enters the congestion zone or in a limited time frame afterwards.
Method of Payment	The payments can be made by smartcards, by credit card, on the internet or by phone call. Smartcards are be provided to users before the implementation, users need to load money on their smartcards before entering the congestion zone if they choose to make the payment with this method.
Exemptions / Discounts	
(1) No charge is levied on Saturdays, Sundays and public holidays.	

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 6

A proposed congestion charging plan in the city will have the following features:

Time	The charge will apply between 07.30 am and 18.30 pm. Daily charge.
Location	Congestion charging will be applied in one area covering 20 km^2 within the city center.
Cost	The cost of the charge will be fixed for all charging hours.
Type of Vehicle	The charges are the same for all type of vehicles.
Date of Payment	The payment should be made during the charging hours once the vehicle enters the congestion zone.
Method of Payment	The payments can be made only by smartcards, which will be provided to users before the implementation. Users need to load money on their smartcards before entering the congestion zone.
Exemptions / Discounts	
(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge. **(3)** In addition, there will be discounts for people living inside the congestion zone.	

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 7

A proposed congestion charging plan in the city will have the following features:

Time	The charge will apply between 07.30 am and 18.30 pm. Daily charge.
Location	Congestion charging will be applied in one area covering 20 km^2 within the city center.
Cost	The cost of the charge will be fixed for all charging hours.
Type of Vehicle	The charges are the same for all type of vehicles.
Date of Payment	The payment should be made during the charging hours once the vehicle enters the congestion zone.
Exemptions / Discounts	
(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge.	

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 8

A proposed congestion charging plan in the city will have the following features:

Time	The charge will apply between 07.30 am and 18.30 pm. Daily charge.
Location	Congestion charging will be applied in one area covering 20 km^2 within the city center.
Cost	The cost of the charge will be fixed for all charging hours.
Type of Vehicle	The charges are the same for all type of vehicles.
Date of Payment	The payment should be made during the charging hours once the vehicle enters the congestion zone.
Exemptions / Discounts	
(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge. **(3)** In addition, there will be discounts for people living inside the congestion zone. **(4)** There will also be discounts if you enter the congestion zone on certain roads.	

O	O	O	O	O	O
0	1	2	3	4	5

PART 2/3

In this part of the survey, you will be presented 9 different choice-making situations. We ask you to consider 2 different congestion charging plans. Consider that each plan has been subjected to public opinion polls and the effectiveness of the plan (reduction in congestion) has been forecasted by researchers. Please mark which of the congestion charging plans you would prefer as a resident of the city.

Choice Situation No: 1

Characteristics	**Congestion Charging Plan A**	**Congestion Charging Plan B**
Public Acceptability	60%	80%
Reduction in Congestion	20%	15%

O O

Choice Situation No: 2

Characteristics	**Congestion Charging Plan A**	**Congestion Charging Plan B**
Public Acceptability	40%	80%
Reduction in Congestion	15%	10%

O O

Choice Situation No: 3

Characteristics	**Congestion Charging Plan A**	**Congestion Charging Plan B**
Public Acceptability	60%	40%
Reduction in Congestion	10%	15%

O O

Choice Situation No: 4

Characteristics	**Congestion Charging Plan A**	**Congestion Charging Plan B**
Public Acceptability	60%	40%
Reduction in Congestion	10%	20%

O O

Choice Situation No: 5

Characteristics	**Congestion Charging Plan A**	**Congestion Charging Plan B**
Public Acceptability	80%	40%
Reduction in Congestion	15%	20%

O O

Choice Situation No: 6

Characteristics	**Congestion Charging Plan A**	**Congestion Charging Plan B**
Public Acceptability	40%	80%
Reduction in Congestion	20%	10%

O O

PART 3/3

In this final part of the survey, we ask you to answer the following questions, which will help us to understand the demographics of the participants.

Please mark your sex.
O Male O Female

What age group are you in?
O 18-25 O 26-35 O 36-50 O 51-60 O 60+

Please mark your education level.
O High school degree O Bachelor's degree O Master's degree or above

How much do you think the public reputation of congestion charges affected your rating?
O Not at all O Somewhat affected O Considerably affected

How beneficial do you think the congestion charge implementation is for yourself individually?
O Not beneficial O Somewhat beneficial O Very beneficial

What effect do you think the congestion charge would have if implemented in your city?
O No effect at all O Somewhat effective O Very effective

Do you drive a car inside the city as your primary mode of transport?
O Yes O No

Thank you for completing the survey. We hope your answers will help municipalities and transport ministries design better charging policies in the future.

1.2. Text of the Main Survey (Including the Rating Experiment and the Stated Choice Experiment)

1.2.1. Block 1

Public Opinion Survey Regarding Congestion Charging Implementations-B1

Congestion charging refers to imposing a charge for vehicles driving in certain parts of a city in order to reduce traffic. Imagine that you are living in a city which is suffering from traffic congestion. There is a plan to implement congestion charges for a certain zone (or zones). Before the implementation of the charges, you are asked for your opinion in terms of the plan's acceptability to you.

In this part of the survey, you will be presented 8 different congestion charging plans and asked to rate them. Congestion charging plans presented in this survey has the following characteristics:

Dimensions of the Congestion Charge: Each congestion charge has either 5 or 6 dimensions. The following five dimensions are default: Time, Location, Cost, Type of Vehicle, Date of Payment. Some congestion charges also have Method of Payment as an additional dimension, thus totaling at 6 dimensions.

Variation within Dimensions: Each charging plan either belongs to Variation 1 or Variation 2.

Dimension	Variation 1	Variation 2
Time	The charge will apply between 07.30 am and 18.30 pm. Daily charge.	The charge will apply between 07.30 am and 18.30 pm. This time frame is divided into 9 time intervals and in each time frame the cost of the charge varies.
Location	Congestion charging will be applied in one area covering 20 km^2 within the city center.	Congestion charging will be applied in two areas covering 10 km^2 each within the city center.
Cost	The cost of the charge will be fixed for all charging hours.	The cost of the charge will vary depending on the area and the time of entry to the zone.
Type of Vehicle	The charges are the same for all type of vehicles.	The charges will also vary depending on the type of vehicles.
Date of Payment	The payment should be made during the charging hours once the vehicle enters the congestion zone.	The payment can be made in advance, during the charging hours once the vehicle enters the congestion zone or in a limited time frame afterwards.
Method of Payment	The payments can be made only by smartcards, which will be provided to users before the implementation. Users need to load money on their smartcards before entering the congestion zone.	The payments can be made by smartcards, by credit card, on the internet or by phone call. Smartcards are provided to users before the implementation, users need to load money on their smartcards before entering the congestion zone if they choose to make the payment with this method.

Exemptions / Discounts: Each congestion charge has a number of exemptions / discounts, ranging from 1 to 4.

The survey will take about 10 minutes of your time.

PART 1/3

Please rate the following congestion charge schemes in terms of their acceptability to you on a scale of 0 to 5; 0 being not acceptable and 5 being fully acceptable. (Note that Variation 1 is colored green and Variation 2 is colored blue to make it easier to separate between the two.)

Congestion Charging Plan No: 1

A proposed congestion charging plan in the city will have the following features:

VARIATION 2 **DIMENSIONS: 5** **EXEMP./DISC: 4**	**1**	**Time**	Divided into 9 time intervals with different charge costs.
	2	**Location**	Multiple areas.
	3	**Cost**	Varies depending on the area and the time of entry.
	4	**Type of Vehicle**	Different charges for different types of vehicles.
	5	**Date of Payment**	Before, during or after the charging hours.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge. **(3)** In addition, there will be discounts for people living inside the congestion zone. **(4)** There will also be discounts if you enter the congestion zone on certain roads.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 2

A proposed congestion charging plan in the city will have the following features:

VARIATION 1 **DIMENSIONS: 5 + 1** **EXEMP./DISC: 2**	**1**	**Time**	Daily charge. 07.30 – 18.30. No different time intervals.
	2	**Location**	One area.
	3	**Cost**	Fixed during charging hours.
	4	**Type of Vehicle**	Same charge for all types of vehicles.
	5	**Date of Payment**	During charging hours only.
	6	**Method of Payment**	One method only.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 3

A proposed congestion charging plan in the city will have the following features:

VARIATION 2 DIMENSIONS: 5 + 1 EXEMP./DISC: 3	**1**	**Time**	Divided into 9 time intervals with different charge costs.
	2	**Location**	Multiple areas.
	3	**Cost**	Varies depending on the area and the time of entry.
	4	**Type of Vehicle**	Different charges for different types of vehicles.
	5	**Date of Payment**	Before, during or after the charging hours.
	6	**Method of Payment**	Multiple methods.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge. **(3)** In addition, there will be discounts for people living inside the congestion zone.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 4

A proposed congestion charging plan in the city will have the following features:

VARIATION 2 DIMENSIONS: 5 + 1 EXEMP./DISC: 4	**1**	**Time**	Divided into 9 time intervals with different charge costs.
	2	**Location**	Multiple areas.
	3	**Cost**	Varies depending on the area and the time of entry.
	4	**Type of Vehicle**	Different charges for different types of vehicles.
	5	**Date of Payment**	Before, during or after the charging hours.
	6	**Method of Payment**	Multiple methods.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge. **(3)** In addition, there will be discounts for people living inside the congestion zone. **(4)** There will also be discounts if you enter the congestion zone on certain roads.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 5

A proposed congestion charging plan in the city will have the following features:

VARIATION 1 DIMENSIONS: 5 EXEMP./DISC: 3	1	**Time**	Daily charge. 07.30 – 18.30. No different time intervals.
	2	**Location**	One area.
	3	**Cost**	Fixed during charging hours.
	4	**Type of Vehicle**	Same charge for all types of vehicles.
	5	**Date of Payment**	During charging hours only.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge. **(3)** In addition, there will be discounts for people living inside the congestion zone.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 6

A proposed congestion charging plan in the city will have the following features:

VARIATION 2 DIMENSIONS: 5 EXEMP./DISC: 2	1	**Time**	Divided into 9 time intervals with different charge costs.
	2	**Location**	Multiple areas.
	3	**Cost**	Varies depending on the area and the time of entry.
	4	**Type of Vehicle**	Different charges for different types of vehicles.
	5	**Date of Payment**	Before, during or after the charging hours.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 7

A proposed congestion charging plan in the city will have the following features:

VARIATION 1 DIMENSIONS: 5 + 1 EXEMP./DISC: 1	1	**Time**	Daily charge. 07.30 – 18.30. No different time intervals.
	2	**Location**	One area.
	3	**Cost**	Fixed during charging hours.
	4	**Type of Vehicle**	Same charge for all types of vehicles.
	5	**Date of Payment**	During charging hours only.
	6	**Method of Payment**	One method only.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 8

A proposed congestion charging plan in the city will have the following features:

VARIATION 1 DIMENSIONS: 5 EXEMP./DISC: 1	1	**Time**	Daily charge. 07.30 – 18.30. No different time intervals.
	2	**Location**	One area.
	3	**Cost**	Fixed during charging hours.
	4	**Type of Vehicle**	Same charge for all types of vehicles.
	5	**Date of Payment**	During charging hours only.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays.		

O	O	O	O	O	O
0	1	2	3	4	5

PART 2/3

In this part of the survey, you will be presented 9 different choice-making situations. Please, put yourself into the shoes of policy makers. Imagine that you are a policy maker in the transport ministry and your decision will affect the structure of the congestion plan. We ask you to consider 2 different congestion charging plans. Consider that each plan has been subjected to public opinion polls and the effectiveness of the plan (reduction in congestion) has been forecasted by researchers. Public acceptability of a plan varies between 40% and 80%, whereas reduction in congestion varies between 10% and 20%. Keep in mind those scales, note that there is a substantial difference between 10% and 20% reduction in congestion. Please mark which of the congestion charging plans you would implement as a policy maker.

Choice Situation No: 1

Characteristics	**Congestion Charging Plan A**	**Congestion Charging Plan B**
Public Acceptability	80%	40%
Reduction in Congestion	10%	15%

O O

Choice Situation No: 2

Characteristics	**Congestion Charging Plan A**	**Congestion Charging Plan B**
Public Acceptability	80%	40%
Reduction in Congestion	15%	20%

O O

Choice Situation No: 3

Characteristics	**Congestion Charging Plan A**	**Congestion Charging Plan B**
Public Acceptability	60%	80%
Reduction in Congestion	15%	10%

O O

Choice Situation No: 4

Characteristics	**Congestion Charging Plan A**	**Congestion Charging Plan B**
Public Acceptability	40%	80%
Reduction in Congestion	20%	10%

O O

Choice Situation No: 5

Characteristics	**Congestion Charging Plan A**	**Congestion Charging Plan B**
Public Acceptability	40%	60%
Reduction in Congestion	20%	15%

O O

Choice Situation No: 6

Characteristics	**Congestion Charging Plan A**	**Congestion Charging Plan B**
Public Acceptability	80%	60%
Reduction in Congestion	10%	20%

O O

Choice Situation No: 7

Characteristics	Congestion Charging Plan A	Congestion Charging Plan B
Public Acceptability	40%	60%
Reduction in Congestion	15%	10%
	O	O

Choice Situation No: 8

Characteristics	Congestion Charging Plan A	Congestion Charging Plan B
Public Acceptability	60%	40%
Reduction in Congestion	10%	20%
	O	O

Choice Situation No: 9

Characteristics	Congestion Charging Plan A	Congestion Charging Plan B
Public Acceptability	60%	80%
Reduction in Congestion	20%	15%
	O	O

PART 3/3

In this final part of the survey, we ask you to answer the following questions, which will help us to understand the demographics of the participants.

Please mark your sex.
O Male O Female

What age group are you in?
O 18-25 O 26-35 O 36-50 O 51-60 O 60+

Please mark your education level.
O High school degree O Bachelor's degree O Master's degree or above

How much do you think the public reputation of congestion charges affected your rating?
O Not at all O Somewhat affected O Considerably affected

How beneficial do you think the congestion charge implementation is for yourself individually?
O Not beneficial O Somewhat beneficial O Very beneficial

How effective do you think the congestion charge would be if implemented in your city?
O Not effective at all O Somewhat effective O Very effective

Do you drive a car inside the city as your primary mode of transport?
O Yes O No

Thank you for completing the survey. We hope your answers will help municipalities and transport ministries design better charging policies in the future.

1.2.2. Block 2

Public Opinion Survey Regarding Congestion Charging Implementations-B2

Congestion charging refers to imposing a charge for vehicles driving in certain parts of a city in order to reduce traffic. Imagine that you are living in a city which is suffering from traffic congestion. There is a plan to implement congestion charges for a certain zone (or zones). Before the implementation of the charges, you are asked for your opinion in terms of the plan's acceptability to you.

In this part of the survey, you will be presented 8 different congestion charging plans and asked to rate them. Congestion charging plans presented in this survey has the following characteristics:

Dimensions of the Congestion Charge: Each congestion charge has either 5 or 6 dimensions. The following five dimensions are default: Time, Location, Cost, Type of Vehicle, Date of Payment. Some congestion charges also have Method of Payment as an additional dimension, thus totaling at 6 dimensions.

Variation within Dimensions: Each charging plan either belongs to Variation 1 or Variation 2.

Dimension	Variation 1	Variation 2
Time	The charge will apply between 07.30 am and 18.30 pm. Daily charge.	The charge will apply between 07.30 am and 18.30 pm. This time frame is divided into 9 time intervals and in each time frame the cost of the charge varies.
Location	Congestion charging will be applied in one area covering 20 km^2 within the city center.	Congestion charging will be applied in two areas covering 10 km^2 each within the city center.
Cost	The cost of the charge will be fixed for all charging hours.	The cost of the charge will vary depending on the area and the time of entry to the zone.
Type of Vehicle	The charges are the same for all type of vehicles.	The charges will also vary depending on the type of vehicles.
Date of Payment	The payment should be made during the charging hours once the vehicle enters the congestion zone.	The payment can be made in advance, during the charging hours once the vehicle enters the congestion zone or in a limited time frame afterwards.
Method of Payment	The payments can be made only by smartcards, which will be provided to users before the implementation. Users need to load money on their smartcards before entering the congestion zone.	The payments can be made by smartcards, by credit card, on the internet or by phone call. Smartcards are provided to users before the implementation, users need to load money on their smartcards before entering the congestion zone if they choose to make the payment with this method.

Exemptions / Discounts: Each congestion charge has a number of exemptions / discounts, ranging from 1 to 4.

The survey will take about 10 minutes of your time.

PART 1/3

Please rate the following congestion charge schemes in terms of their acceptability to you on a scale of 0 to 5; 0 being not acceptable and 5 being fully acceptable. (Note that Variation 1 is colored green and Variation 2 is colored blue to make it easier to separate between the two.)

Congestion Charging Plan No: 1

A proposed congestion charging plan in the city will have the following features:

VARIATION 2 **DIMENSIONS: 5** **EXEMP./DISC: 1**	**1**	**Time**	Divided into 9 time intervals with different charge costs.
	2	**Location**	Multiple areas.
	3	**Cost**	Varies depending on the area and the time of entry.
	4	**Type of Vehicle**	Different charges for different types of vehicles.
	5	**Date of Payment**	Before, during or after the charging hours.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 2

A proposed congestion charging plan in the city will have the following features:

VARIATION 2 **DIMENSIONS: 5 + 1** **EXEMP./DISC: 2**	**1**	**Time**	Divided into 9 time intervals with different charge costs.
	2	**Location**	Multiple areas.
	3	**Cost**	Varies depending on the area and the time of entry.
	4	**Type of Vehicle**	Different charges for different types of vehicles.
	5	**Date of Payment**	Before, during or after the charging hours.
	6	**Method of Payment**	Multiple methods.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 3

A proposed congestion charging plan in the city will have the following features:

VARIATION 1 DIMENSIONS: 5 + 1 EXEMP./DISC: 4	1	**Time**	Daily charge. 07.30 – 18.30. No different time intervals.
	2	**Location**	One area.
	3	**Cost**	Fixed during charging hours.
	4	**Type of Vehicle**	Same charge for all types of vehicles.
	5	**Date of Payment**	During charging hours only.
	6	**Method of Payment**	One method only.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge. **(3)** In addition, there will be discounts for people living inside the congestion zone. **(4)** There will also be discounts if you enter the congestion zone on certain roads.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 4

A proposed congestion charging plan in the city will have the following features:

VARIATION 2 DIMENSIONS: 5 EXEMP./DISC: 3	1	**Time**	Divided into 9 time intervals with different charge costs.
	2	**Location**	Multiple areas.
	3	**Cost**	Varies depending on the area and the time of entry.
	4	**Type of Vehicle**	Different charges for different types of vehicles.
	5	**Date of Payment**	Before, during or after the charging hours.
	6	**Method of Payment**	Multiple methods.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge. **(3)** In addition, there will be discounts for people living inside the congestion zone.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 5

A proposed congestion charging plan in the city will have the following features:

VARIATION 2 **DIMENSIONS: 5 + 1** **EXEMP./DISC: 1**	**1**	**Time**	Divided into 9 time intervals with different charge costs.
	2	**Location**	Multiple areas.
	3	**Cost**	Varies depending on the area and the time of entry.
	4	**Type of Vehicle**	Different charges for different types of vehicles.
	5	**Date of Payment**	Before, during or after the charging hours.
	6	**Method of Payment**	Multiple methods.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 6

A proposed congestion charging plan in the city will have the following features:

VARIATION 1 **DIMENSIONS: 5 + 1** **EXEMP./DISC: 3**	**1**	**Time**	Daily charge. 07.30 – 18.30. No different time intervals.
	2	**Location**	One area.
	3	**Cost**	Fixed during charging hours.
	4	**Type of Vehicle**	Same charge for all types of vehicles.
	5	**Date of Payment**	During charging hours only.
	6	**Method of Payment**	One method only.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge. **(3)** In addition, there will be discounts for people living inside the congestion zone.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 7

A proposed congestion charging plan in the city will have the following features:

VARIATION 1 DIMENSIONS: 5 EXEMP./DISC: 2	1	**Time**	Daily charge. 07.30 – 18.30. No different time intervals.
	2	**Location**	One area.
	3	**Cost**	Fixed during charging hours.
	4	**Type of Vehicle**	Same charge for all types of vehicles.
	5	**Date of Payment**	During charging hours only.
	6	**Method of Payment**	One method only.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge.		

O	O	O	O	O	O
0	1	2	3	4	5

Congestion Charging Plan No: 8

A proposed congestion charging plan in the city will have the following features:

VARIATION 1 DIMENSIONS: 5 EXEMP./DISC: 4	1	**Time**	Daily charge. 07.30 – 18.30. No different time intervals.
	2	**Location**	One area.
	3	**Cost**	Fixed during charging hours.
	4	**Type of Vehicle**	Same charge for all types of vehicles.
	5	**Date of Payment**	During charging hours only.
	6	**Method of Payment**	One method only.
	Exemptions / Discounts		
	(1) No charge is levied on Saturdays, Sundays and public holidays. **(2)** Motorbikes, mopeds and emergency vehicles are exempt from the charge. **(3)** In addition, there will be discounts for people living inside the congestion zone. **(4)** There will also be discounts if you enter the congestion zone on certain roads.		

O	O	O	O	O	O
0	1	2	3	4	5

PART 2/3

In this part of the survey, you will be presented 9 different choice-making situations. Please, put yourself into the shoes of policy makers. Imagine that you are a policy maker in the transport ministry and your decision will affect the structure of the congestion plan. We ask you to consider 2 different congestion charging plans. Consider that each plan has been subjected to public opinion polls and the effectiveness of the plan (reduction in congestion) has been forecasted by researchers. Public acceptability of a plan varies between 40% and 80%, whereas reduction in congestion varies between 10% and 20%. Keep in mind those scales, note that there is a substantial difference between 10% and 20% reduction in congestion. Please mark which of the congestion charging plans you would implement as a policy maker.

Choice Situation No: 1

Characteristics	Congestion Charging Plan A	Congestion Charging Plan B
Public Acceptability	80%	40%
Reduction in Congestion	10%	15%
	O	O

Choice Situation No: 2

Characteristics	Congestion Charging Plan A	Congestion Charging Plan B
Public Acceptability	80%	40%
Reduction in Congestion	15%	20%
	O	O

Choice Situation No: 3

Characteristics	Congestion Charging Plan A	Congestion Charging Plan B
Public Acceptability	60%	80%
Reduction in Congestion	15%	10%
	O	O

Choice Situation No: 4

Characteristics	Congestion Charging Plan A	Congestion Charging Plan B
Public Acceptability	40%	80%
Reduction in Congestion	20%	10%
	O	O

Choice Situation No: 5

Characteristics	Congestion Charging Plan A	Congestion Charging Plan B
Public Acceptability	40%	60%
Reduction in Congestion	20%	15%
	O	O

Choice Situation No: 6

Characteristics	Congestion Charging Plan A	Congestion Charging Plan B
Public Acceptability	80%	60%
Reduction in Congestion	10%	20%
	O	O

Choice Situation No: 7

Characteristics	Congestion Charging Plan A	Congestion Charging Plan B
Public Acceptability	40%	60%
Reduction in Congestion	15%	10%
	O	O

Choice Situation No: 8

Characteristics	Congestion Charging Plan A	Congestion Charging Plan B
Public Acceptability	60%	40%
Reduction in Congestion	10%	20%
	O	O

Choice Situation No: 9

Characteristics	Congestion Charging Plan A	Congestion Charging Plan B
Public Acceptability	60%	80%
Reduction in Congestion	20%	15%
	O	O

PART 3/3

In this final part of the survey, we ask you to answer the following questions, which will help us to understand the demographics of the participants.

Please mark your sex.
O Male O Female

What age group are you in?
O 18-25 O 26-35 O 36-50 O 51-60 O 60+

Please mark your education level.
O High school degree O Bachelor's degree O Master's degree or above

How much do you think the public reputation of congestion charges affected your rating?
O Not at all O Somewhat affected O Considerably affected

How beneficial do you think the congestion charge implementation is for yourself individually?
O Not beneficial O Somewhat beneficial O Very beneficial

How effective do you think the congestion charge would be if implemented in your city?
O Not effective at all O Somewhat effective O Very effective

Do you drive a car inside the city as your primary mode of transport?
O Yes O No

Thank you for completing the survey. We hope your answers will help municipalities and transport ministries design better charging policies in the future.

Appendix III

1.1. Regression Analysis Results for the Pilot Rating Experiment

Regression Analysis: Rating versus Complexity

Method
Weights Weight

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	1	2959,4	2959,36	27,82	0,000
Complexity	1	2959,4	2959,36	27,82	0,000
Error	118	12552,6	106,38		
Lack-of-Fit	4	288,6	72,16	0,67	0,614
Pure Error	114	12264,0	107,58		
Total	119	15512,0			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
10,3140	19,08%	18,39%	16,04%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-4,0	11,3	-0,36	0,721	
Complexity	5,44	1,03	5,27	0,000	1,00

Regression Equation
Rating = -4,0 + 5,44 Complexity

Fits and Diagnostics for Unusual Observations

Obs	Rating	Fit	Resid	Std Resid	
33	0,00	55,81	-55,81	-2,43	R
34	0,00	72,13	-72,13	-3,18	R
36	0,00	66,69	-66,69	-2,06	R
37	0,00	66,69	-66,69	-2,06	R
57	0,00	55,81	-55,81	-2,43	R
58	0,00	72,13	-72,13	-3,18	R
59	0,00	50,37	-50,37	-2,20	R
60	0,00	66,69	-66,69	-2,06	R
61	0,00	66,69	-66,69	-2,06	R

R Large residual

1.2. Regression Analysis Results for the Main Rating Experiment

Regression Analysis: Rating versus Complexity

Method

Weights Weight

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	1	5913,3	5913,29	97,71	0,000
Complexity	1	5913,3	5913,29	97,71	0,000
Error	734	44421,5	60,52		
Lack-of-Fit	9	378,6	42,06	0,69	0,716
Pure Error	725	44042,9	60,75		
Total	735	50334,8			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
7,77945	11,75%	11,63%	11,19%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	22,56	3,67	6,15	0,000	
Complexity	3,166	0,320	9,88	0,000	1,00

Regression Equation

Rating = 22,56 + 3,166 Complexity

Fits and Diagnostics for Unusual Observations

Obs	Rating	Fit	Resid	Std Resid	
3	20,00	70,05	-50,05	-2,25	R
4	20,00	73,22	-53,22	-2,40	R
67	20,00	70,05	-50,05	-2,25	R
128	100,00	41,56	58,44	2,63	R
131	20,00	70,05	-50,05	-2,25	R
132	20,00	73,22	-53,22	-2,40	R
203	20,00	70,05	-50,05	-2,25	R
204	20,00	73,22	-53,22	-2,40	R
272	100,00	41,56	58,44	2,63	R
288	100,00	41,56	58,44	2,63	R
377	0,00	57,39	-57,39	-2,47	R
378	0,00	66,89	-66,89	-2,08	R
379	0,00	54,22	-54,22	-2,33	R
529	0,00	57,39	-57,39	-2,47	R
530	0,00	66,89	-66,89	-2,08	R

561	0,00	57,39	-57,39	-2,47	R
562	0,00	66,89	-66,89	-2,08	R
643	0,00	54,22	-54,22	-2,33	R
681	0,00	57,39	-57,39	-2,47	R
682	0,00	66,89	-66,89	-2,08	R
683	0,00	54,22	-54,22	-2,33	R
691	0,00	54,22	-54,22	-2,33	R

R Large residual

1.3. Parameter Estimates for the Pilot Stated Choice Experiment

Model:	Logit
Number of estimated parameters:	2
Number of observations:	90
Number of individuals:	90
Null log likelihood:	-62.383
Cte log likelihood:	-62.383
Init log likelihood:	-62.383
Final log likelihood:	-54.295
Likelihood ratio test:	16.177
Rho-square:	0.13
Adjusted rho-square:	0.098
Final gradient norm:	4.78E-09
Diagnostic:	Convergence reached...
Iterations:	4
Run time:	00:00
Variance-covariance:	from analytical hessian
Sample file:	pilot.dat

Utility parameters									
Name	**Value**	**Std err**	**t-test**	**p-value**		**Robust Std err**	**Robust t-test**	**p-value**	
B_EF	0.0773	0.0718	1.08	0.28	*	0.0717	1.08	0.28	*
B_PA	0.0437	0.0172	2.54	0.01		0.0171	2.55	0.01	

Utility functions			
Id	**Name**	**Availability**	**Specification**
1	Alt1	av1	B_PA * PA1 + B_EF * EF1
2	Alt2	av2	B_PA * PA2 + B_EF * EF2

Correlation of coefficients										
Coefficient 1	**Coefficient 2**	**Covariance**	**Correlation**	**t-test**	**p-value**		**Rob. cov.**	**Rob. corr.**	**Rob. t-test**	**p-value**
B_EF	B_PA	0.00111	0.895	0.59	0.56	*	0.00109	0.891	0.59	0.56

Smallest singular value of the hessian: 185.3

1.4. Parameter Estimates for the Main Stated Choice Experiment

Model:	Logit
Number of estimated parameters:	2
Number of observations:	828
Number of individuals:	828
Null log likelihood:	-573.926
Cte log likelihood:	-573.887
Init log likelihood:	-573.926
Final log likelihood:	-554.161
Likelihood ratio test:	39.531
Rho-square:	0.034
Adjusted rho-square:	0.031
Final gradient norm:	1.06E-05
Diagnostic:	Convergence reached...
Iterations:	3
Run time:	00:00
Variance-covariance:	from analytical hessian
Sample file:	main exp.dat

Utility parameters									
Name	**Value**	**Std err**	**t-test**	**p-value**		**Robust Std err**		**Robust t-test**	**p-value**
B_EF	0.105	0.0223	4.7	0		0.0223		4.7	0
B_PA	0.0338	0.00569	5.94	0		0.00569		5.94	0

Utility functions			
Id	**Name**	**Availability**	**Specification**
1	Alt1	av1	B_PA * PA1 + B_EF * EF1
2	Alt2	av2	B_PA * PA2 + B_EF * EF2

Correlation of coefficients									
Coefficient 1	**Coefficient 2**	**Covariance**	**Correlation**	**t-test**	**p-value**	**Rob. cov.**	**Rob. corr.**	**Rob. t-test**	**p-value**
B_EF	B_PA	0.000113	0.893	4.08	0	0.000113	0.894	4.09	0

Smallest singular value of the hessian: 199.999

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