How does the level of congestion charging complexity affect public acceptability?

A. Mandev*

Faculty of Technology, Policy and Management, Delft University of Technology, Netherlands

March 2017

Abstract

The lack of acceptability is one of the main obstacles to the implementation of congestion charges. 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 this paper, first a definition of different levels of congestion charging complexity is made; then a rating experiment is performed to measure the acceptability levels of the public towards different complexity levels. The data from the rating experiment is analyzed through a regression analysis. A sensitivity analysis is performed by investigating how the results of this research would change if only certain demographic groups from the experiment were taken as reference. The results show that there is a significant positive relationship between public acceptability and complexity levels. Acceptability increases as the level of complexity increases. This result proved to be robust in the sensitivity analysis as well. A possible future research topic is to estimate how individual dimensions of a complexity level actually impact the complexity, in order to improve the definition of complexity levels; in this paper, it was assumed that each dimension contributes equally to the level of complexity.

Keywords: Congestion charging, complexity, acceptability, rating experiment, regression analysis

*Ahmet Mandev – 4420519, e-mail: A.Mandev@student.tudelft.nl

1. Introduction

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). 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). Fürst and Dieplinger's (2014) state that social norms, personal outcome expectations and perceived effectiveness are the most influential factors that affect acceptability, which account for more than 50% of the criterion variance. Schade and Schlag (2003)'s research in Como, Athens, Dresden and Oslo also confirm that these three factors are the most influential ones.

These three factors are studied by different researchers in different cities, and there is substantial material in the literature regarding those. 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'. This suggests that there is a vagueness when it comes to the relationship between complexity and acceptability.

The research question of this paper is: How does the level of congestion charging complexity affect public acceptability? A rating experiment and regression analysis of the data collected through that experiment were used as the research methods. Definition complexity levels is given in Section 2, the design of the rating experiment is explained in Section 3, the results of the regression analysis is given in Section 4, a sensitivity analysis is performed in Section 5, and conclusion to the paper is given in Section 6.

When it comes to the topic of acceptability of congestion charges, the concept of fairness is also part of the discussion. Eliasson (2016) states that there is no objective way to measure or define fairness. Researchers 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. 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). In this paper, the main perspective that is taken into account is the consumer's perspective, because the rating 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. However, this does not undermine the relationship between complexity and acceptability; instead it just further implies that fairness and complexity are positively correlated.

2. Definition of complexity levels

First of all, a definition of complexity that applies to all cases must be made. 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. Bonsall et al. (2007) define the factors that increase complexity as the following: "(1) the number of dimensions on which the charges vary (e.g. time, location, type of vehicle, date of payment, method of payment, etc.), (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 et al., 2007). Based on these factors, the complexity level of a congestion charging plan can be estimated.

Complexity can be expressed as a function of those five factors. However, in order to define complexity as such, another research on its own which compares the relationship between those factors must be made. Such a research falls beyond the scope of this paper. Instead, among those factors, the most representative of complexity in total has been chosen to define the complexity in this paper, which is: the total number of charge levels which a user might be subjected to.

Previous congestion charging implementations in Stockholm, Gothenburg, London, Milan and Singapore were observed; and according to those observations, the legend given in Table 1 was reached at, which shows how a complexity level is calculated.

Dimension	Definition of 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 only one type of vehicle, complexity increases 1 level. If there are multiple 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.
Definition of Levels within Exemptions / Discounts	
Each category of exemption / discounts will increase the complexity level by 1.	

Table 1:Definition of Levels within Dimensions and Exemptions / Discounts

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 nine 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.

Another factor of complexity is 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 wording of the charge can irrationally increase the complexity. In order to prevent this, the levels within exemptions/discounts are going to be counted not as individual exemptions, but as categories. For instance, if there is an exemption on Saturdays, Sundays and during Christmas; they will be categorized as 'day exemptions' and only add 1 level to the total complexity level.

3. The rating experiment

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 on real-life charging plans in Stockholm, Gothenburg, London, Milan and Singapore. 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.

Normally, each dimension can have any one of those two 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]. This is again based on real-life congestion charging implementations. 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.)

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.

Table 2: Description of Attributes and Their Levels in the Rating Experiment

Aside from the rating questions, the respondents in the survey were asked seven additional questions in order to build a demographic data. 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. This data was used in the sensitivity analysis to see how the results of the experiment would change if only certain demographic groups were taken as reference.

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. Ngene provided the following results.

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’.					

Table 3: Design of the Rating Experiment

The rating is done on a scale of 0 to 5. The participants of the experiment are asked to rate the given alternative; 0 being not acceptable and 5 being fully acceptable. These ratings are converted to a 0-100 scale during the regression analysis.

The survey was separated into 2 blocks in order to not overwhelm the respondents. 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 published on my private 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. There were 92 respondents who participated in the survey.

4. 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.

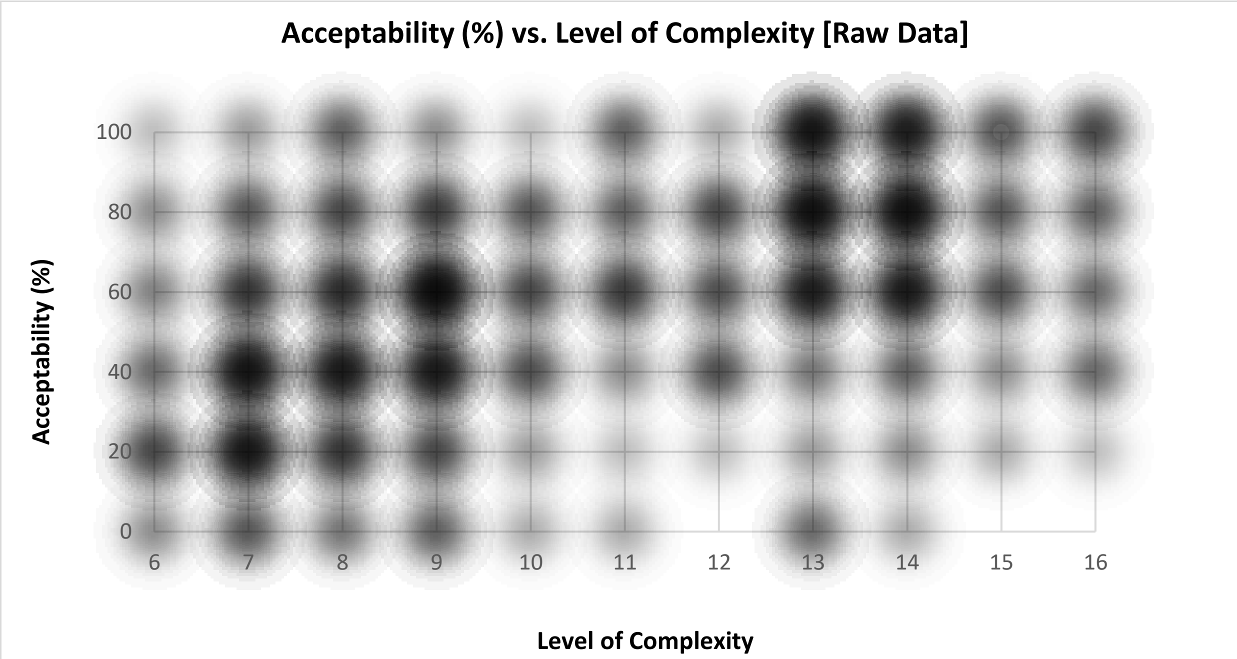

Figure 1: Raw Data for Acceptability vs. Level of Complexity – Main Experiment

Some complexity levels can be achieved by different structures. 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. This creates an uneven number of observations among complexity levels. Therefore, a weighted regression analysis was used to analyze the data. Additionally, a multiple regression analysis was performed to see how individual attributes of complexity affect acceptability. A significance level of 0.05 was used.

The weighted regression analysis in Minitab software gives the following regression equation for acceptability (A) and complexity level (CL):

$$A = 22.56 + 3.166\ CL$$

The results indicated a significant relationship with p-value less then 0.05. Rho-square is 11.75% which indicates a substantial level of unobserved heterogeneity. The line plot for the regression equation is given below.

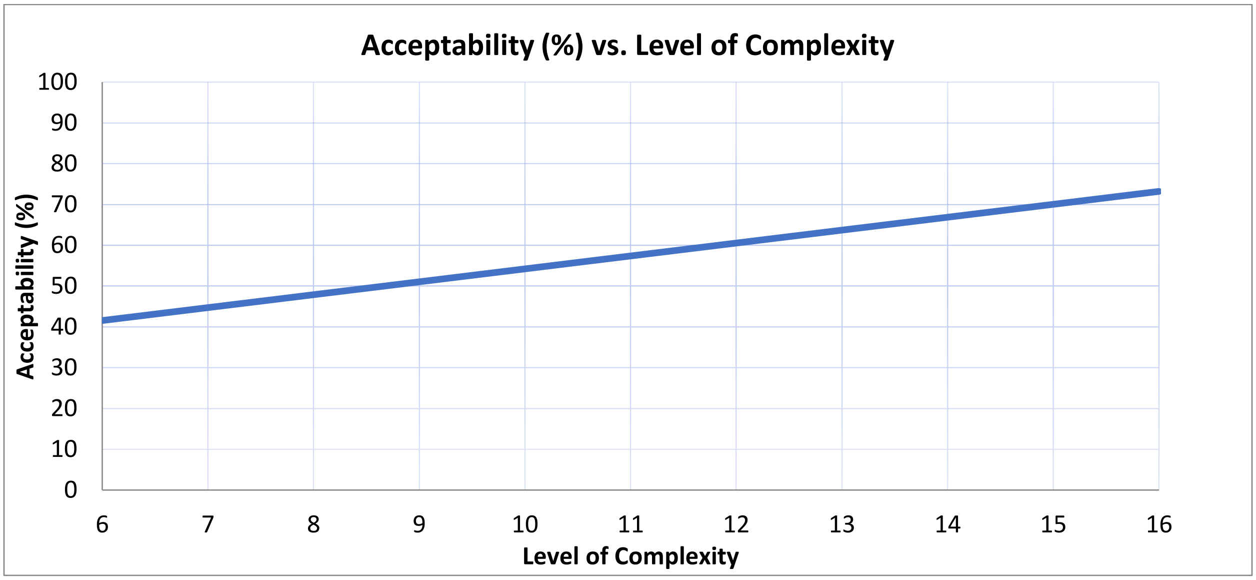

Figure 2: Line Plot for Acceptability vs. Level of Complexity

The multiple regression analysis 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.

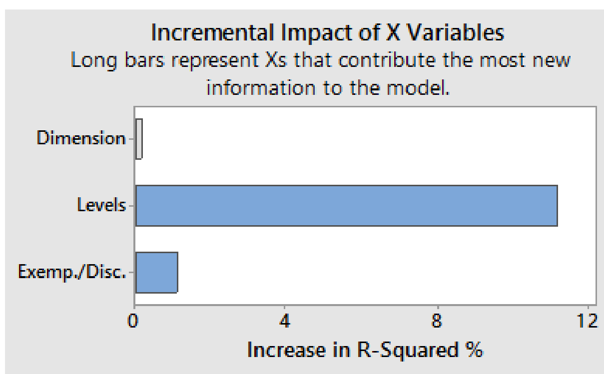

Figure 3: Impact of the Individual Attributes of Complexity Levels on Acceptability

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.

5. Sensitivity analysis

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

5.1. Based on social norms

The respondents were asked if the reputation of congestion charges affected their decision making. The following answers were given:

Reputation of Congestion Charges Affecting Their Decision	
Not at all	26%
Somewhat affected	45%
Considerably affected	29%

Table 4: Percentage Distribution of the Answers to the Social Norm Question

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

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

Table 5: Re-estimated Acceptability Functions Based on Social Norms

The line plots for these acceptability functions are given below.

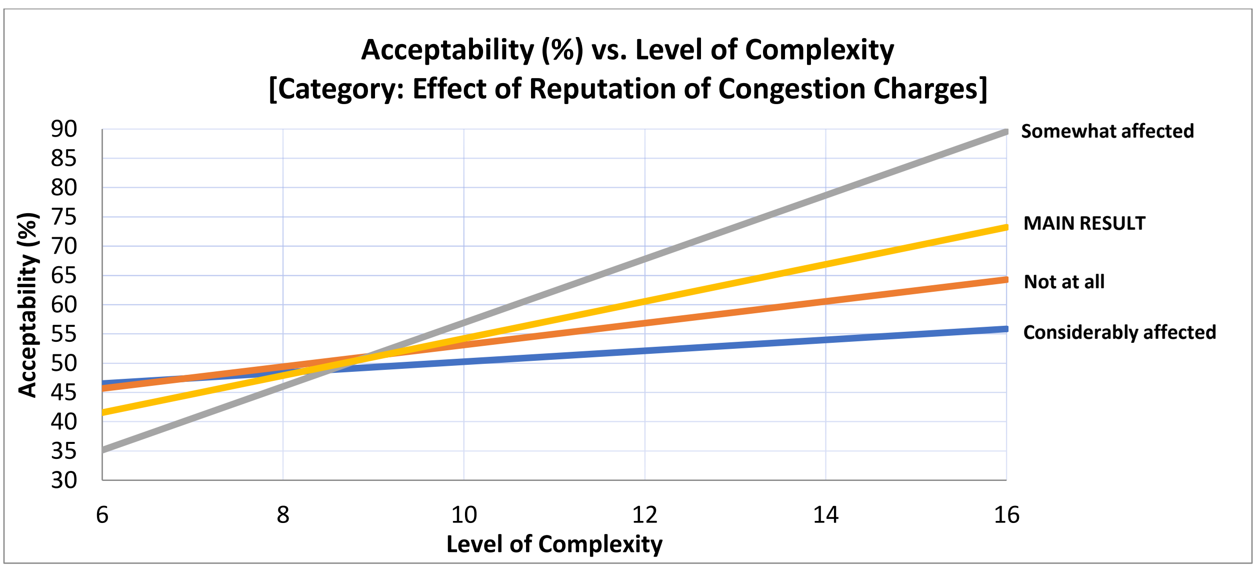

Figure 4: Line Plot for Acceptability vs. Level of Complexity Based on Social Norms

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.

5.2. Based on personal outcome expectations

The survey 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:

Individual Benefits from a Future Congestion Charging Implementation	
Not beneficial	21%
Somewhat beneficial	60%
Very beneficial	19%

Table 6: Percentage Distribution of the Answers to the Personal Outcome Expectation Question

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

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

Table 7: Re-estimated Acceptability Functions Based on Personal Outcome Expectations

The line plots for these acceptability functions are given below.

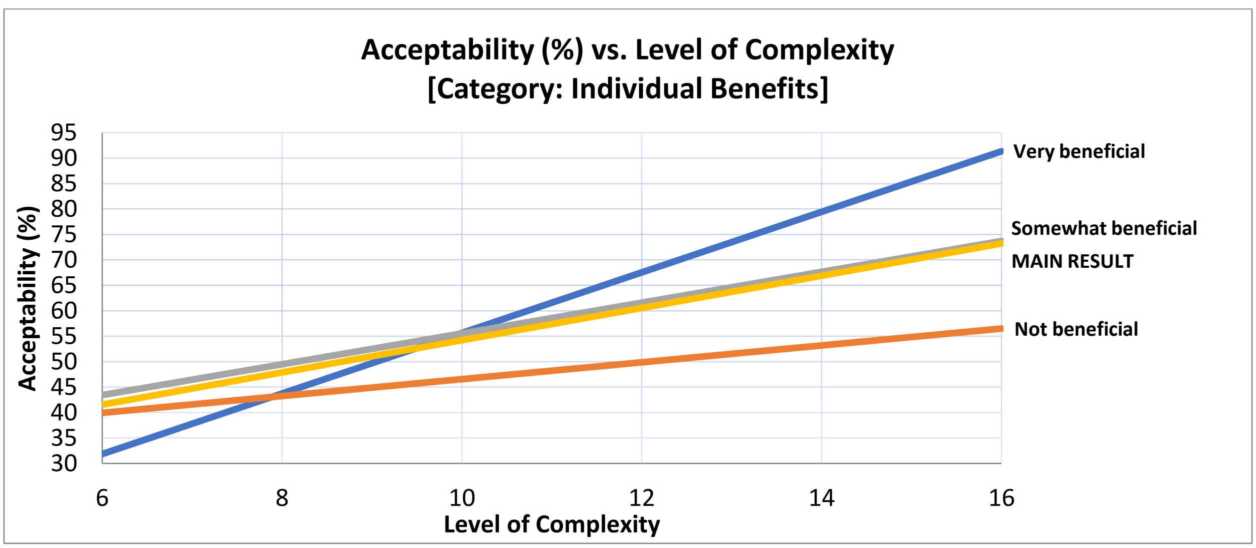

Figure 5: Line Plot for Acceptability vs. Level of Complexity Based on Personal Outcome Expectations

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.

5.3. Based on perceived effectiveness

The survey 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:

Anticipated Effect of A Future Congestion Charging Implementation	
Not effective at all	12%
Somewhat effective	70%
Very effective	18%

Table 8: Percentage Distribution of the Answers to the Perceived Effectiveness Question

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

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

Table 9: Re-estimated Acceptability Functions Based on Perceived Effectiveness

The line plots for these acceptability functions are given below.

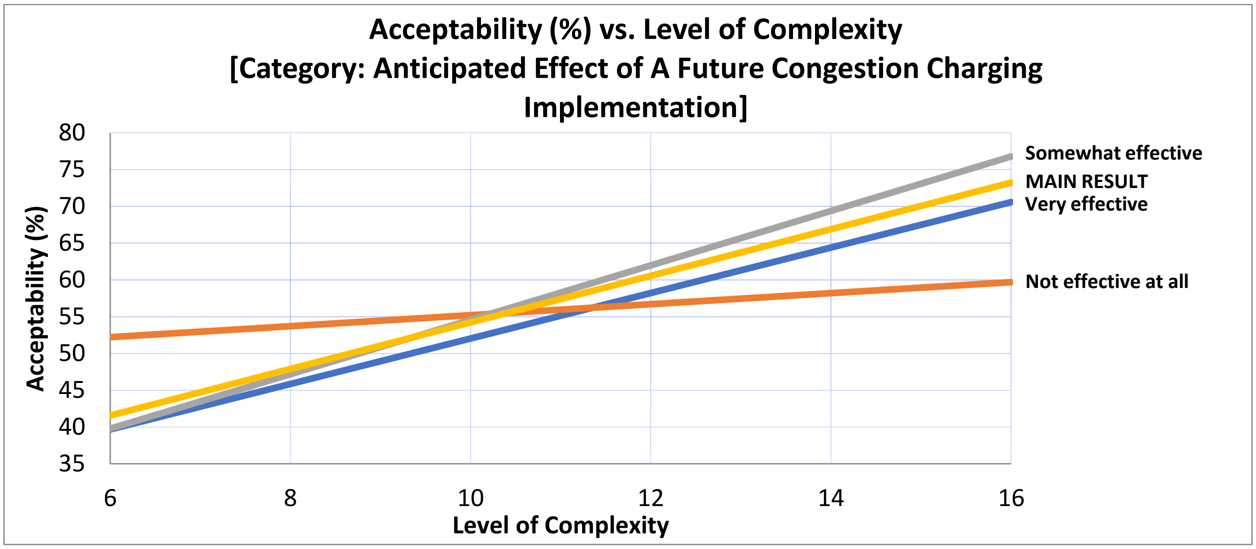

Figure 6: Line Plot for Acceptability vs. Level of Complexity Based on Perceived Effectiveness

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 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 function and fall closely near the main result.

5.4. 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:

Driver	
Yes	22%
No	78%

Table 10: Percentage Distribution of Answers to the Driver Question

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

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

Table 11: Re-estimated Acceptability Functions Based on the Driver Question

The line plots for these acceptability functions are given below.

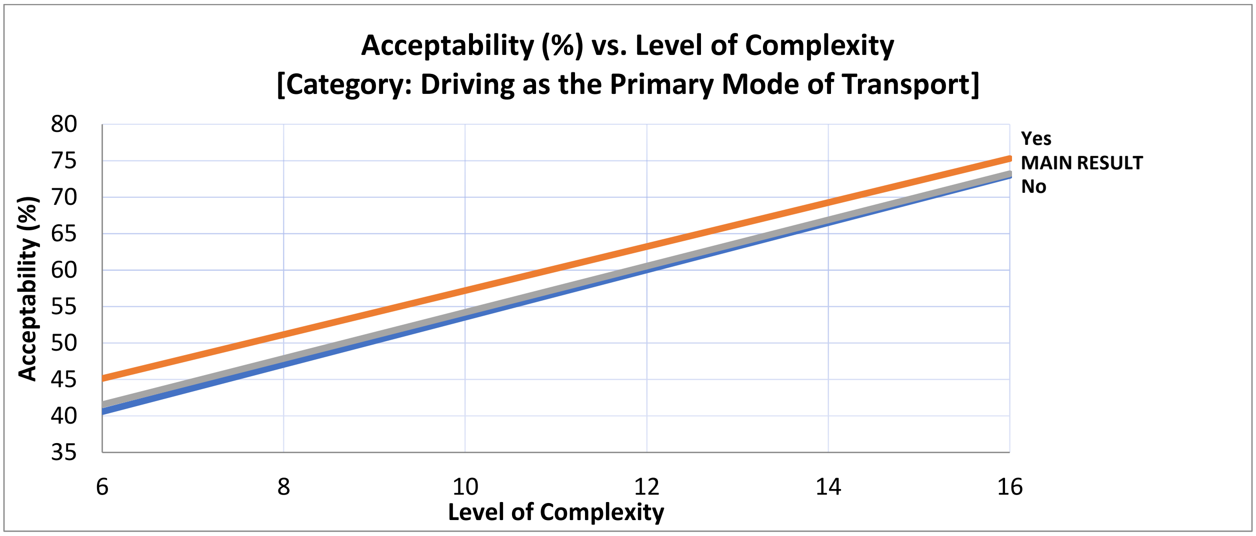

Figure 7: Line Plot for Acceptability vs. Level of Complexity Based on the Driver Question

The line plots show that there are no drastic differences between the acceptability functions. Both response group are very close to the main acceptability function. The response group 'yes' tends to have slightly higher acceptability levels overall compared to the rest of the population.

5.5. Based on sex

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

Sex	
Male	59%
Female	41%

Table 12: Percentage Distribution of Answers to the Sex Question

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

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

Table 13: Re-estimated Acceptability Functions Based on Sex

The line plots for these acceptability functions are given below.

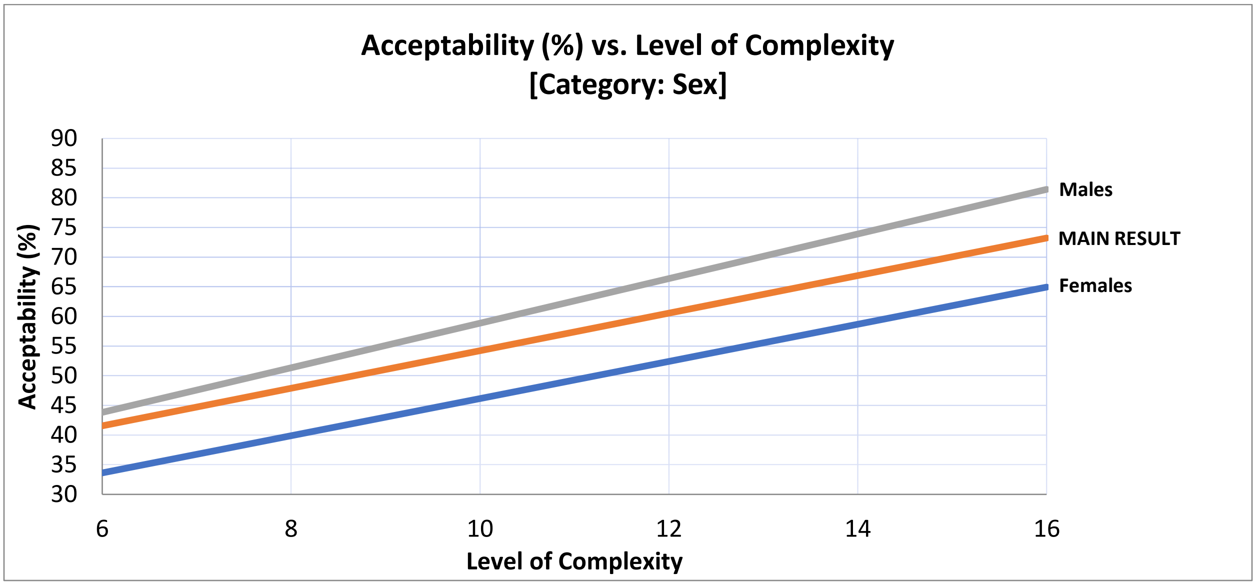

Figure 8: Line Plot for Acceptability vs. Level of Complexity Based on Sex

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. If males and females had equal ratios amongst respondents, the main acceptability function would become less steep and have lower acceptability levels overall.

5.6. Based on age

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

Age	
18-25	40%
26-35	29%
36-50	18%
51-60	13%
60+	0%

Table 14: Percent Distribution of Answers to the Age Question

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

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

Table 15: Re-estimated Acceptability Functions Based on Age

The line plots for these acceptability functions are given below.

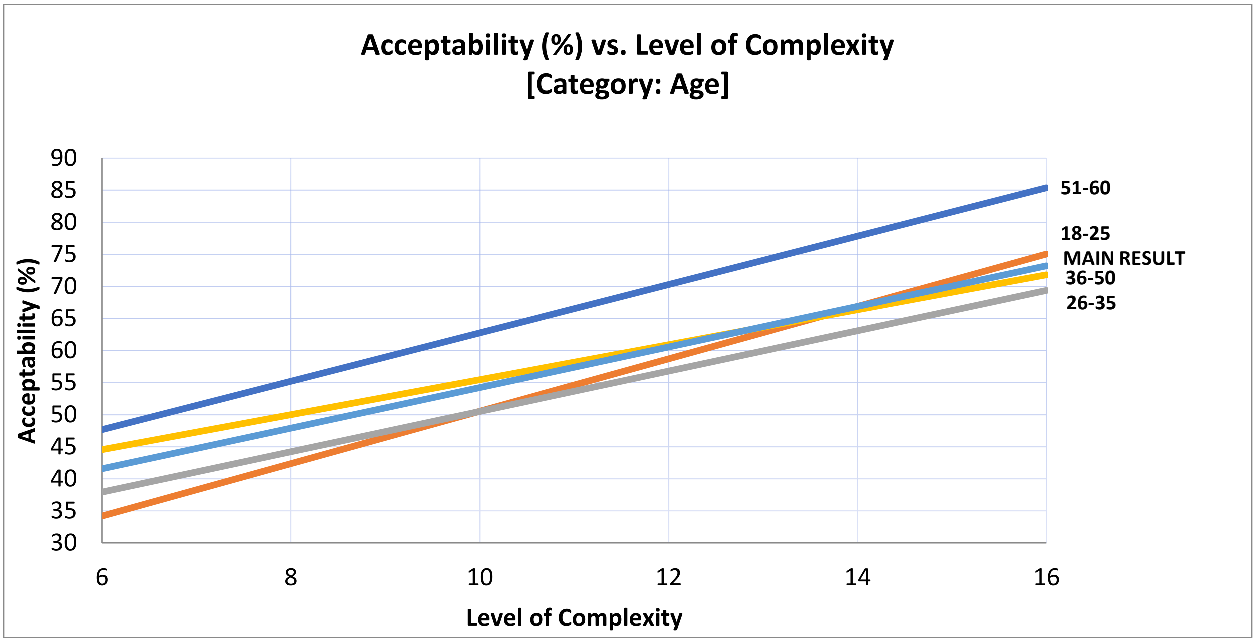

Figure 9: Line Plot for Acceptability vs. Level of Complexity Based on Age

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.

5.7. Based on education level

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

Education	
High school degree	0%
Bachelor's degree	37%
Master's degree or above	63%

Table 16: Percent Distribution of Answers to the Education Question

There were no respondents with only a high school degree. The re-estimated acceptability functions for each response group is given below.

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

Table 17: Re-estimated Acceptability Functions Based on Education

The line plots for these acceptability functions are given below.

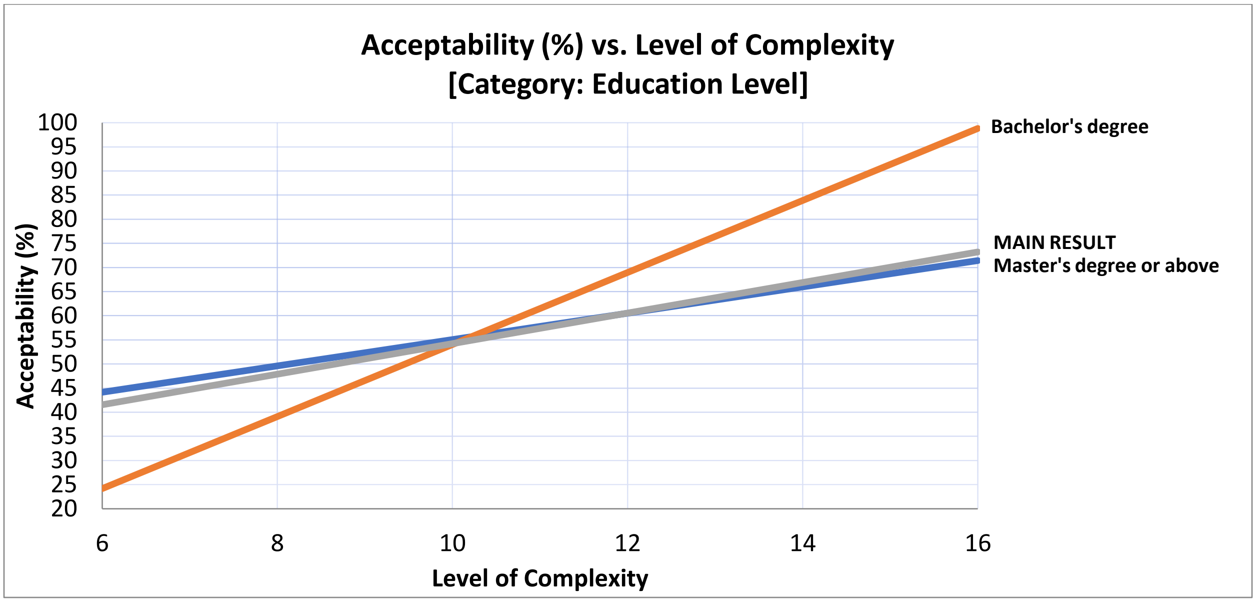

Figure 10: Line Plot for Acceptability vs. Level of Complexity Based on Education

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. If there were more respondents with bachelor's degrees, we would expect the acceptability function to be steeper.

6. Conclusion

The sensitivity analysis shows that all response groups have positive acceptability functions. This proves that the main acceptability function is robust in its direction. Therefore, in respect to the research question of this paper, it can be concluded that public acceptability increases as the complexity level increases based on the definition of complexity levels given in this paper.

A possible future research topic is to estimate how individual dimensions of a complexity level actually impact the complexity, in order to improve the definition of complexity levels; in this paper, it was assumed that each dimension contributes equally to the level of complexity.

References

Bonsall, P., Shires, J., Ngoduy, D., Link, H., Papaioannou, P., & Xanthopoulos, P. (2007). *Optimal Complexity of Prices for Transport Infrastructure*.

Börjesson, M., & Kristoffersson, I. (2014). Assessing the welfare effects of congestion charges in a real world setting. *Transportation Research Part E: Logistics and Transportation Review*, *70*(1), 339–355. https://doi.org/10.1016/j.tre.2014.07.006

de Palma, A., Lindsey, R., & Proost, S. (2007). Chapter 12 Synthesis of case study results and future prospects. *Research in Transportation Economics*, *19*(7), 269–297. https://doi.org/10.1016/S0739-8859(07)19012-0

Eliasson, J. (2016). Is congestion pricing fair? Consumer and citizen perspectives on equity effects. *Transport Policy*, *52*, 1–15. https://doi.org/10.1016/j.tranpol.2016.06.009

Fürst, E. W. M., & Dieplinger, M. (2014). The acceptability of road pricing in Vienna: The preference patterns of car drivers. *Transportation*, *41*(4), 765–784. https://doi.org/10.1007/s11116-013-9485-2

Grisolía, J. M., López, F., & Ortúzar, J. de D. (2015). Increasing the acceptability of a congestion charging scheme. *Transport Policy*, *39*, 37–47. https://doi.org/10.1016/j.tranpol.2015.01.003

Polančič, G., & Cegnar, B. (2016). Complexity Metrics for Process Models – A Systematic Literature Review. *Computer Standards & Interfaces*, *51*(July 2016), 104–117. https://doi.org/10.1016/j.csi.2016.12.003

Schade, J., & Schlag, B. (2003). Acceptability of urban transport pricing strategies. *Transportation Research Part F: Traffic Psychology and Behaviour*, *6*(1), 45–61. https://doi.org/10.1016/S1369-8478(02)00046-3