The Interaction Of Context And Demography In Equity Effects Of Congestion Pricing

A case study of Stockholm

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ABSTRACT

The equity effect of congestion pricing has been advocated to be given enough concern for its acceptability. This thesis aimed to explore the mixed effects in travel behaviour changing caused by congestion charging in demography factors (social economic status) and context factors (location, flexibility, access to car and possession of long-term public transport card). In order to understand by what mechanisms congestion pricing affects the equity, structural equation modelling was applied to model the causal networks in the case study of Stockholm congestion charge. Results revealed a more complicated influence from different combination of factors. The location relative to charging cordon mattered for the trip-making both directly and indirectly through the transport mode preference. The work schedule flexibility should be also taken into consideration when considering the time-based scheme. The mixed effects between two groups of factors suggested that more factors should be considered when justifying the privileged group and disadvantaged group to implement the policy. The method used in this thesis could be very constructive for equity effect evaluation in other cities with different conditions.

Key words: congestion charge; equity; travel behaviour; structural equation modelling

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SUMMARY

Equity effects are advocated to be given enough concern when making transportation policy in order to gain the public support. Congestion charging is considered to be effective in reducing congestion by charging to change the travel behaviour. How to achieve the equity among certain groups of people was the main concern of this thesis. More factors were involved in the study which include both demographic factors such as social economic status and context factors such as home location, mode preference and work schedule flexibility. Since Stockholm congestion charging is time and cordon-based scheme, changing of the trips might not solely depend on the demography factors; the context factors could not be neglected.

In order to express more complicated causal effects, structural equation modelling was applied in two years of panel-based travel dairy data by drawing the causal networks. SEM could show the complex relationships between several variables including exogenous variables, endogenous variables and dependent variables by performing a series of regression.

More than 10 models were examined based on a series of hypotheses using the survey data from 2004 and 2006 in Stockholm. Four notable models on contextual factors were presented and analysed in details. The results showed that simply considering the demography factors when justifying the equity was not enough, the mechanism through the contextual factors was also notable. There were not only significant effects on trips caused by the contextual factors but also interactive influences within the factor groups. The location relative to the charging cordon was found to influence the trips either directly or through the mode preference. Potential reverse effects were also found in this study that the preference of the mode choice also influenced the residence location choice. The work schedule flexibility was found significant through the mode preference of car, which is corresponding to the effects of time-based scheme.

It was suggested in this study that in order to achieve a more fair congestion charging policy, more factors should be taken into consideration to understand how it affects equity. More study should be done to find out certain groups of people combining the social economic status and the contextual factors to justify the ‘winners’ and the ‘losers’ in equity studies.

1 INTRODUCTION

1.1 EQUITY EFFECTS OF CONGESTION PRICING

Congestion pricing has been considered and applied as an effective way to deal with congestion problems in urban areas. However, the public acceptability could be low due to the trade-off of effectiveness and equity effects. While evaluating the effectiveness such as the reduction of the congestion and emission of the measure, the equity effects should be given enough concern for giving support to its implementation and improvement.

When implementing a taxation policy, both horizontal equity and vertical equity are taken into consideration. Horizontal equity refers to the extent to which individuals within a 'group' defined by several factors, for example, same social economic status (gender, income, age) are treated similarly. It means that individuals with similar ability to pay should pay the similar amounts or adjust behaviours in the same way. The discrimination should be eliminated in same groups. The vertical equity refers to the extent to which members of different groups are treated similarly. A transportation policy is progressive if it favours the disadvantaged travellers, while it is regressive if it imposes more burdens to the disadvantaged travellers (Chu, 2013).

After the Stockholm congestion charging scheme was introduced, a series of studies have examined how travel behaviours have been affected by the charging system. Among the equity effect evaluations, more explicit measures can be done to reveal the effect on changing behaviours from congestion charges of demographic and context factors both separately and interactively. This could help us to discuss the equity effects not only in terms of aggregate effects on different demographic groups but also in terms of the mechanisms for its effects on different groups (Franklin, 2012). This study will be based on the study of context factors – work schedule flexibility, access to a car, possession of a long-term transit pass and commuting cross the cordon, excavating more related effects by using different causal results as well as evaluating the interactional effects between themselves. This might help us better distinguish the beneficial group and disadvantaged group which can/cannot cope with the congestion pricing by paying or adjusting behaviour. And it can provide a better understanding to the travel behaviour changes in more specific groups.

To sum up, the centre research question of this thesis is to find out by what mechanism congestion pricing affect equity. This study was done by evaluating different affecting factors in detail.

1.2 CONGESTION CHARGE IN STOCKHOLM

Stockholm congestion charge (Swedish: Trängselskatt i Stockholm) is a toll system implemented to charge fees on auto vehicles. It charges certain amount of fees while vehicles entering or exiting the city centre. The system was set up as a cordon charging scheme (Figure 1-1), vehicles would be required to pay certain amount of fee according to the time of the day (Svensk författningssamling 2004:629, 2004). Travels before 6.30 and after 18.30 or on weekends are free of charge. July which is summer time is also excluded from charging period. The charging fee varied from 10 Swedish kroners (SEK) to 20SEK according to the peak hours (Table 1-1). Certain types of vehicles such as public transport, motorcycles, and emergency vehicles were exempted.

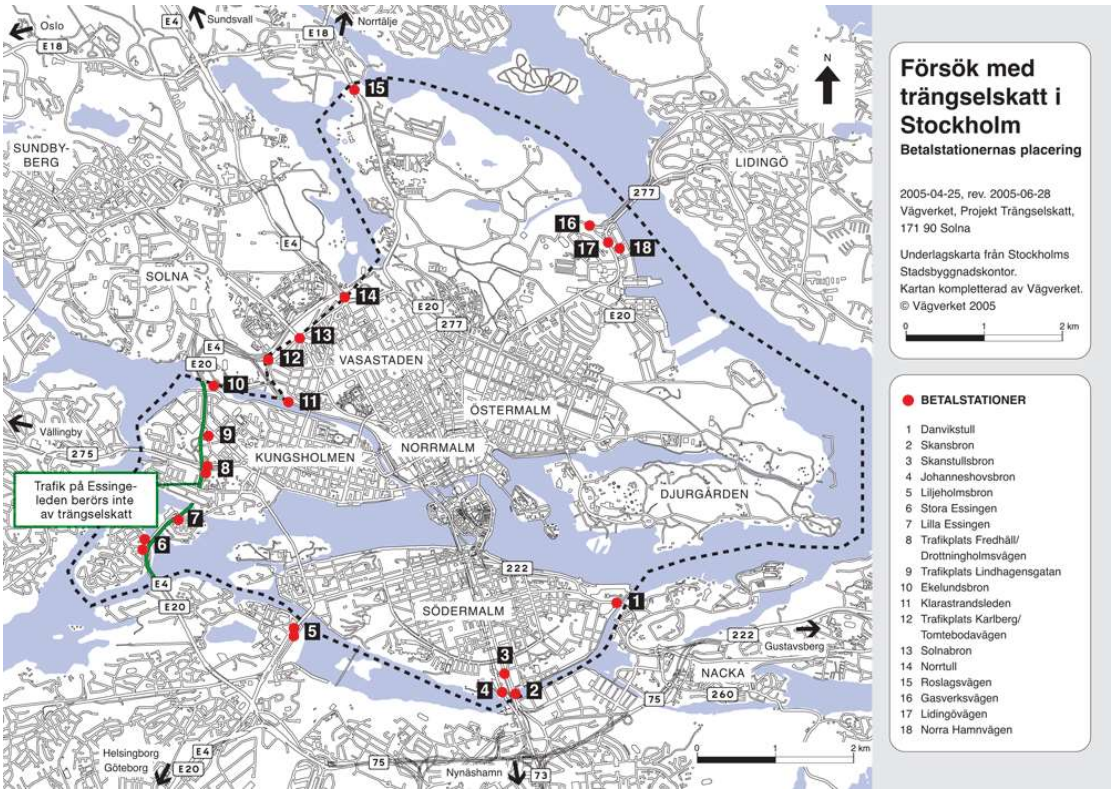
Table 1-1 Table of the charging differed by the time

Time	6.30-6.59	7.00-7.29	7.30-8.29	8.30-8.59	9.00-15.29	15.30-15.59	16.00-17.29	17.30-17.59	18.00-18.29
Fee (SEK)	10	15	20	15	10	15	20	15	10

Source: (Svensk författningssamling 2004:629, 2004)

It was first introduced as a trial basis during January 3–July 31 2006. After six months of testing and evaluation, as well as collecting public opinions, the congestion charges were reintroduced in August 2007. The study in this thesis was based on the data of the trial in year 2006.

The congestion charging was forced to make an effort to improve public transit services, breaking down physical, geographical, economic and time barriers to mobility. Research on the policy (Eliasson & Jonsson, 2011) reveals that public support for congestion charging grew as a result of several factors: a new and improved image by the media, a change in travel habits that users became more accustomed to, a strong environmental ethic, and a better understanding of how the system worked.



Source: Stockholmsförsöket, http://www.stockholmsforsoket.se/

Figure 1-1 Map of Stockholm congestion charges

2 LITERATURE REVIEW

2.1 DEMOGRAPHIC AND CONTEXTUAL EFFECTS

Travel behaviours are influenced not simply just by demographic factors such as age, gender and income, but also by the contexts such as car access, location and work flexibility. The effects differ from different areas and cultures under different circumstances. The mixed effects bring much complexity to the travel behaviours.

For gender factors, according to Scandinavian studies, it is shown that even in a country like Sweden, which is often considered to have a relatively high degree of gender equality, men are driving considerably more, and using less public transport, compared to women (Olof, 2002). The historical study based on Sweden (Frandberg & Vilhelmson, 2011) found that gender difference regard to travel behaviour has been reduced over the period but is still substantial.

Also, the gender difference is not affecting the behaviour independently, it was found to be influenced by a wide variety of variables, including age, employment status, household income, number of cars, and travel purpose (Liu & Lu, 2013). There might be more behind gender differences in travel behaviour than just social roles. Gender differences in travel mode choice even in households with as many cars as drivers suggest that preferences may be at play (Scheiner & Holz-Rau, 2012). The complexity is caused from the interactive effects of both demographic and contextual factors such as the location, the access to the car, work flexibility. Gender factor was found to be significant only when the contextual factors were included (Franklin, 2012).

As for other factors, there could be the same interaction between demographic and contextual factors. Age and access to company cars are also important while larger income group has a much larger probability of using the car (Olof, 2002).

With respect to the geographic locations, the cordon pricing has been considered as unfair since there are drivers travelling within the cordon area while there are other drivers who need to exit and enter the cordon several times a day (Ecola & Light, 2010). As a result, it might be possible that working and living at the different side of the cordon would have interactive influence towards the mode preference hence influence the number of auto trips. The choices of travel mode were identified to be composed of constraints and possibilities set by the

person's mobility resources, which are provided by the residential locations (Næss, 2005), therefore, direct effects from residential location to the possession or access to a car are worth investigating. Reversely, there could be psychological effects of travel behaviour on preference of residential location choice (Choocharukul, et al., 2008). Modes of transport were found to be highly related to the choice of residential area. Individuals who prefer driving might have the tendency to live in more driving-friendly environment. The inconvenience caused by charging fee might have influence for individuals choosing the residential places.

2.2 EQUITY EFFECT STUDIES BASED ON STOCKHOLM

Previous studies suggested that the Stockholm congestion taxes negatively affect the inner city more than other areas, man more than women, employed people more than others, high-income individuals more than low-income individuals, say, the high-income man in inner city paid the most (Transek, 2006). However, the total effects are determined by how revenues are used (Eliasson & Mattsson, 2006). The effects also varied while taking the travel time saving into account, males which are considered travelling more might benefit more from the travel time saving than females, the paid group experience better travel time than low-income people who do detours to avoid paying also lost (Karlström & Franklin, 2009).

Since the charging scheme is time-based, it was assumed that commuters might change the departure time. During the study of morning commuters (Karlström & Franklin, 2009), highly persistent for departure time choice with a weak effect of switching to an earlier time were revealed.

By dividing the mixed factors into demographic and contextual factors, the study of context role in congestion pricing (Franklin, 2012) found that contextual factors had significant mediating effects at the relationships between demographic effects and the changing on trips by car. It is necessary to include the endogenous factors to find out the significant variable in equity effect evaluation.

2.3 STRUCTURAL EQUATION MODELLING

Structural equation modelling is an extremely flexible linear-in-parameters multivariate statistical modelling technique (Golob, 2003). The method is

particularly useful in the identification of the direct impact of one variable on another and the variable's possible impact through a mediator (Silva, 2012). An SEM could be used to capture the causal influences (regression effects) of large numbers of exogenous variables (which are the variables with no causal links leading to them from other variables in the model) on the endogenous variables (which have explicit causes within the model); and the causal influences of endogenous variables upon one another. It is a confirmatory, rather than exploratory method, because the models are required to have reasonable theories for the unidirectional effects to be constructed. The structural model also allows specification of error-term covariance. It can be used to demonstrate the situation that the presence of some mediating variables changes the relationship between the other variables. SEM could be regarded as the combination of moderation and mediation models (Figure 2-1). The regression effects can be described by using the path coefficients through different paths.

The advantage of SEM compared to other liner regression estimates is that it allows 1) involving both manifest (which is directly observed) and latent (not directly observed but inferred from other variables) variables, 2) testing a model overall rather than individually, 3) modelling mediating factors, 4) handling of non-normally distributed data, 5) modelling error term relationships (Golob, 2003). These advantages provided a good condition to evaluate a causal network that involves a lot of factors and correlations.

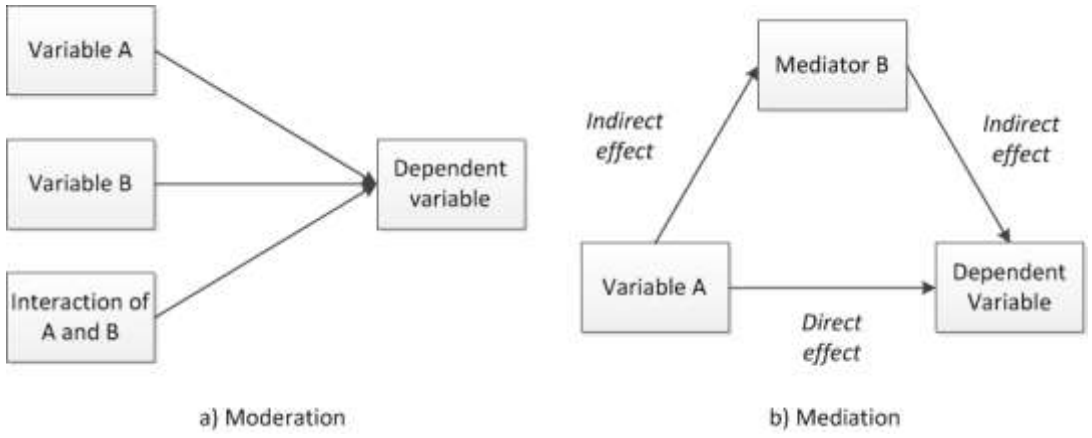


Figure 2-1 Diagram of Moderation and Mediation

A general SEM model is composed with a series of regression analysis, which can be concluded into three parts: the latent variable links and two measurement

parts specifying how the observed exogenous/ endogenous variables relate to the latent exogenous/ endogenous constructs. In other words,

- a measurement model for the endogenous (dependent)variables
- a measurement sub model for the exogenous (independent) variables
- a structural (sub)model, all of which are estimated simultaneously.

Without latent variables:

$$y = \mathbf{B}y + \mathbf{\Gamma}\mathrm{x} + \zeta$$

Where y is a column vector of endogenous variables and x is a column vector of exogenous variables. **B** is a matrix containing the structural effects from endogenous to other endogenous variables and **Γ** is a matrix containing the structural effects from exogenous to endogenous variables. ζ indicates the error term associated with an endogenous variable.

When the model involves latent variables which are manifested by other factors, there should be measurement model of the latent variables:

The measurement model of latent exogenous variables (which would be applied):

$$x = \mathbf{\Lambda}_x \xi + \delta$$

The measurement model of latent exogenous variables (which would not be applied in this thesis):

$$y = \mathbf{\Lambda}_y \xi + \varepsilon$$

Here **Λ** is a matrix containing the structural coefficients linking the observed and latent exogenous(x)/ endogenous(y) variables, δ and ε indicate the measurement errors in observed exogenous/ endogenous variables.

In order to better understand the structure of the causal networks, path diagrams are always used to visualize the relationships. An example path diagram is presented here:

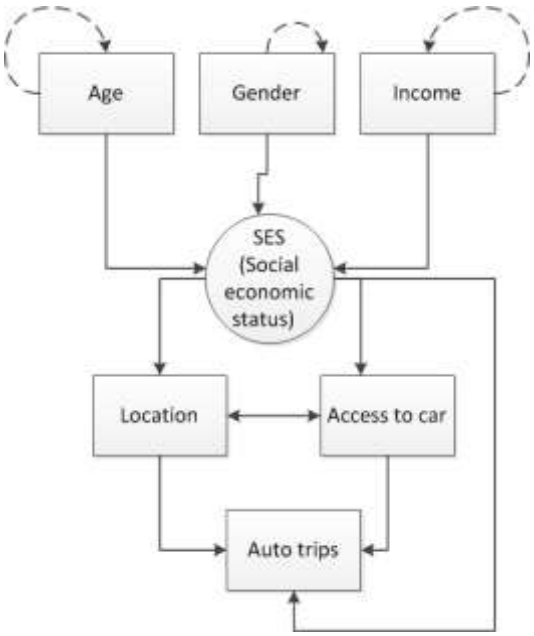


Figure 2-2 Path diagram example

The factor in the circle is a latent variable manifested by three exogenous variables, influencing the other two endogenous variables which have effects on each other; and they together have effect on the dependent variable. There are also direct effects from the latent variable to dependent variable.

Table 2-1 The effects in SEM model

Effect component	Exogenous to Endogenous	Endogenous to Endogenous
direct effect	$\boldsymbol{\Gamma}$	$\mathbf{B}$
indirect effect	$(\mathbf{I}-\mathbf{B})^{-1}\boldsymbol{\Gamma}-\boldsymbol{\Gamma}$	$(\mathbf{I}-\mathbf{B})^{-1}-\mathbf{I}-\mathbf{B}$
total effect	$(\mathbf{I}-\mathbf{B})^{-1}\boldsymbol{\Gamma}$	$(\mathbf{I}-\mathbf{B})^{-1}-\mathbf{I}$

According to the path diagram, a more readable network could be interpreted. There are three kinds of effects could be estimated from the models: the direct effect (DE), indirect effect (IE) and the total effect (TE). The DE is the direct effect from an independent variable on a dependent variable in a defined path, represented by the structural coefficient which links the two variables, for example in Figure 2-2, SES to auto trips in the direct line is a total effect. IE indicates the effects of one variable to another variable through mediating variables, which is expressed by the products of the coefficients. In the path diagram, there is an indirect effect between SES with auto trips through location.

The sum of all the DE and IE is considered to be the total effects of the SEM model. The calculation is summarized in Table 2-1.

The constructed models in this thesis were based on the theoretical hypothesis. In order to test the model fit, there are many statistical tests could be applied in SEM.

- **P-value (Chi-Square test)**. This is a fundamental measurement of fit in most of the model fit measures. The test indicates the difference between observed and expected covariance matrices. Values closer to zero indicate a better fit.
- **Comparative Fit Index (CFI).** The CFI (Hu & Bentler, 1999) analyses the model fit by examining the discrepancy between the data and the proposed model. CFI values range from 0 to 1, with larger values indicating better fit; a CFI value of 0.9 or larger generally indicates acceptable model fit (BENTLER, 1990).
- **Akaike information criterion (AIC).** AIC (Akaike, 1974) deals with the trade-off between the goodness of fit of the model and the complexity of the model, which attains a penalised maximum log-likelihood. It could be used as a test of relative model fit: The preferred model is the one with the lowest AIC value. (Akaike, 1980)
- **Root Mean Square Error of Approximation (RMSEA)** The root mean square error of approximation (RMSEA) is aim to avoid issues of sample size by analysing the discrepancy between the hypothesized model, with optimally chosen parameter estimates, and the population covariance matrix. The RMSEA ranges from 0 to 1, with smaller values indicating better model fit (Hu & Bentler, 1999). A value of 0 .06 or less is indicative of acceptable model fit.

3 DATA DESCRIPTION

3.1 THE SURVEY

The Stockholm congestion charging was first introduced as a trial from January 3rd to July 31st, 2006. A panel travel survey was carried out as a form of a travel dairy in a particular day both in year 2004 and year 2006, as a result the travel behaviour change could be observed by the difference from two waves. In the two waves, the response rates were 48% and 69%, respectively. Out of 77000 surveys, the effective surveys which involving the participation of both waves were chosen and several filters were applied in the data set. The filters excluded those who changed social economic status (change employment) and the null values. Finally 6054 observations were used in the SEM model.

The useful variables derived from the travel survey are: IDs, including the travel ID and the traveller's ID; Years, indicating the source; age; gender; household income; Locations, mode choice, purpose, indicator of across the cordon, working schedule flexibility, car ownership, long-term transportation card(SL card) ownership, number of trips for auto and public transport.

3.2 THE DATASET

The filtered dataset has 6054 observations which could be applied in the SEM model. Useful variables were extracted from the dataset. Basically, two kinds of factors were involved, demographic factors which can show the social economic status, and the contextual factors showing the mechanism.

The variables are listed below:

- Age: the age of the individuals.
- Gender: the gender of the individuals, dummy variable, 1 for male, 0 for female
- Income: the income of the household per month, using the mid-point income, kSEK
- Home and work location 04/06: the home location and work location factors according to the cordon, dummy variable, 1 for needing to cross the cordon during commuting, 0 for not needing to cross the cordon
- Access to car 04/06: access to car in each year, dummy variable, 0 for 'no', 1 for 'yes'
- SL card 04/06: access to long-term public transport card (SL card) in each year, dummy variable, 0 for 'no', 1 for 'yes'

- Flexibility 04/06: the factor for work schedule flexibility, dummy variable, 1 for having a flexible work schedule, 0 for not having a flexible work schedule

Table 3-1 Summary of the exogenous and endogenous variables

Variable	Category	Frequency	Encoding	Mean	Min	Max	SD
Age(10 years)	NA	NA	NA	4,564	1	8	1,4542
Gender	Male	2914	1	0,4813	0	1	0,4997
	Female	3140	0				
Income(kSEK/month)	0-7,5	17	3,75	49,93	3,75	100	25,3633
	7,5-10	36	8,75				
	10-15	132	12,5				
	15-25	720	20				
	25-40	1553	32,5				
	40-55	1603	47,5				
	55-70	1069	62,5				
	70+	924	100				
Location 2004 (commute cross the cordon)	Yes	4186	1	0,6914	0	1	0,4490
	No	1868	0				
Location 2006 (commute cross the cordon)	Yes	4218	1	0,6967	0	1	0,4597
	No	1836	0				
Flexible work schedule 2004	Yes	2633	1	0,4349	0	1	0,4958
	No	3421	0				
Flexible work schedule 2006	Yes	2652	1	0,4381	0	1	0,4962
	No	3402	0				
Access to car 2004	Always	5973	1	0,9866	0	1	0,1149
	Never	81	0				
Access to car 2006	Always	5972	1	0,9865	0	1	0,1156
	Never	82	0				
Public transport card 2004	Always	2758	1	0,4556	0	1	0,4981
	Never	3296	0				
Public transport card 2006	Always	2838	1	0,4688	0	1	0,4991
	Never	3216	0				

Table 3-2 Summary of the dependent variables

Dependent Variable	Mean	Min	Max	SD
Auto Trips 2004	1.786	0	10	2.165117
Auto Trips 2006	1.656	0	10	2.011721
PT Trips 2004	0.4542	0	7	0.948433
PT Trips 2006	0.4566	0	7	0.952019

- Auto trips 04/06: auto trips by one individual per day
- Public transport trips 04/06: public transport trips by one individual per day

The characteristic of the data and variables were summarized in Table 3-1 and Table 3-2.

The summary of the data is a total result of each year which cannot indicate the underlying individual changing effects. But through it we can see that the auto trips were reduced in year 2006 and the public transport trips were increased respectively. There were differences in two years in all the context factors which could not be simply interpreted by the aggregative effects. In the following section, SEM will be applied to evaluate the disaggregate effects.

4 METHODOLOGY

4.1 HYPOTHESES

This study continued the study of the role of the context (Franklin, 2012), more hypotheses were made and tested among those factors based on theories and empirical studies.

The previous model is shown in Figure 4-1. The direct relationships between each group of factors are evaluated using the dependent variable of change in car trips.

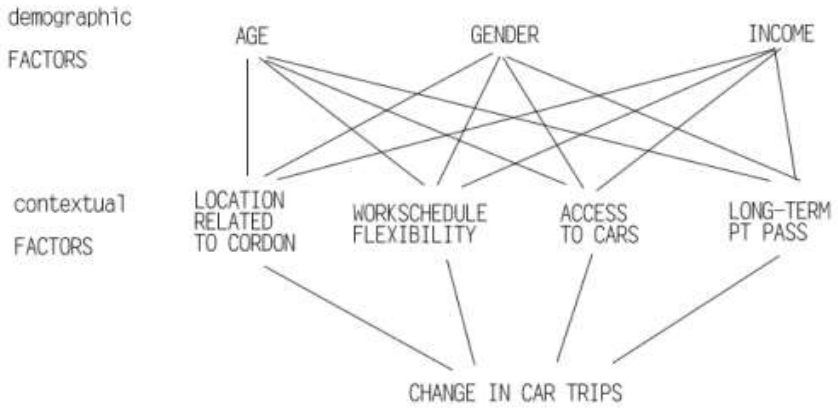


Figure 4-1 Role of context factor in equity study (Franklin, 2012)

More hypotheses were made when considering within each group of factors. The interactions within and between each group of factors were explored.

For example, the car ownership preferences stems from both demographic characteristics and unobserved household factors (Bhat & Guo, 2007). The mode preference based on residential location is significant according to most of equity effect studies. The person's mobility and connectivity in geographical location affect car travelling (Næss, 2005). In accessible areas with more transit and restrictions on automobiles, people own fewer vehicles but make more trips (Shay & Khattak, 2012).

According to the cordon based scheme of the congestion charging, it could be assumed that commuting across the cordon might inevitably have the impact on

the preference of driving. The reverse effect might also exist that the preference regarding residential location was significantly affected by behavioural intention towards car usage (Choocharukul, et al., 2008). As a result, it was worth investigating if there was an interaction between residence location regarding to the cordon and the car access in this case.

The same effect from location to long-term public transport card ownership could be assumed. Living and working in the different sides of cordon could reduce the auto trips, as a result leading to more public transport trips, either directly or through the mediating factor of the mode choice.

Also, the flexibility of work schedule might change the travel behaviour since the charging is time-based. Workers with flexible schedules were found to prefer avoiding the peak hours (He, 2013), especially performing in a late departure (Karlström & Franklin, 2009). From here it can be assumed that the flexibility might also play a subtle role within the context factor group as well as with the other group.

What's more, the car ownership factor would be negatively related to the ownership of long-term transport card but the sensitivity towards the policy might be in different scales since there might be complicity between the social economic status and the contextual factors.

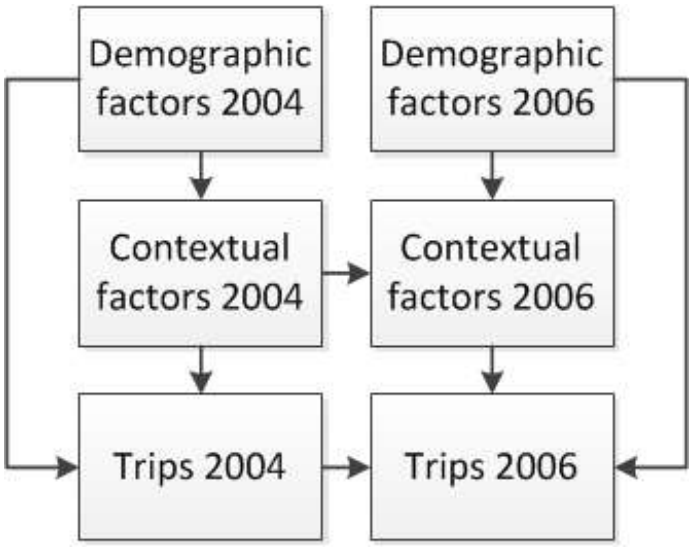


Figure 4-2 Assumptions between year 2004 and year 2006

More assumed networks are described in Figure 4-2 and Figure 4-3. Figure 4-2 displays the causal effects between demographic and contextual factors regarding to the trips. It was assumed that the demographic factors would influence the trips both directly and indirectly through the contextual factors. Between the two years there were also causal relationships from year 2004 to year 2006. Figure 4-3 demonstrates the interaction of context factors in detail. The location factor and the flexibility of schedule might have effects on transport mode choice in both ways.

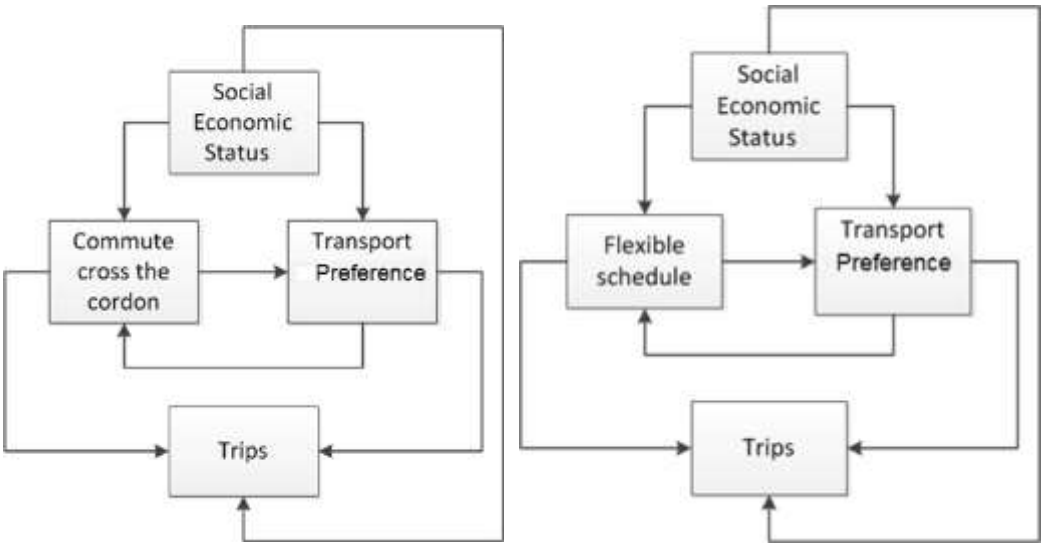


Figure 4-3 Assumptions of the interaction of the context factors

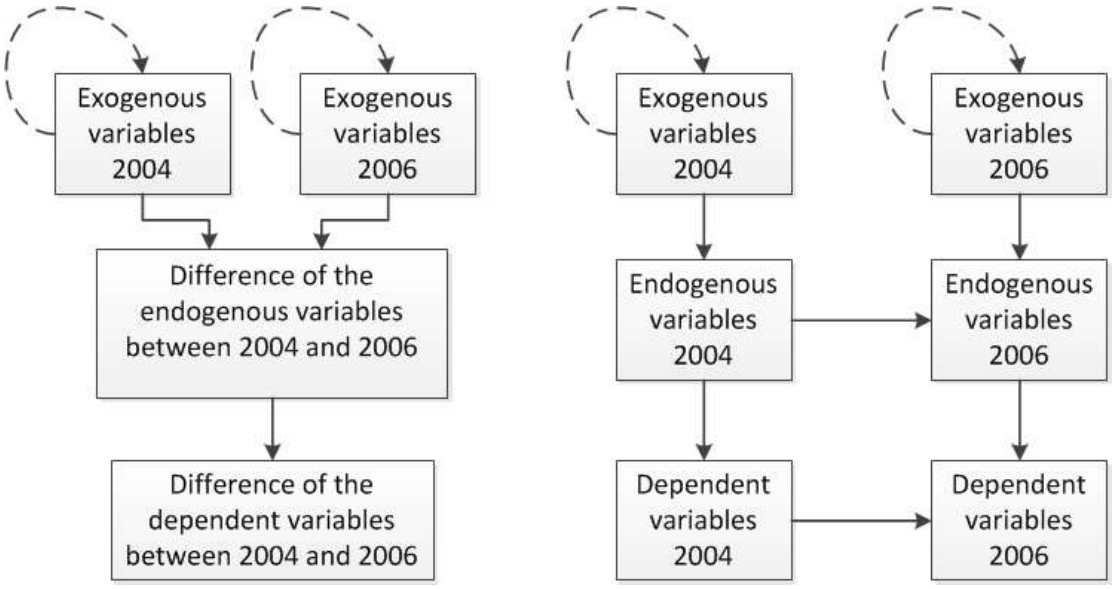
To sum up, the hypotheses would be:

- Different demographic groups change travel behaviour through different contextual factors, gender differs from transport mode preference, age and income differ from location and flexibility
- Commuting across the cordon would play a role for decreasing auto trips both indirectly through the mode preference and directly
- The transport mode preference(access to the car, possession of long term public transport card) would influence making auto trips and public transport trips directly and indirectly through the geographical location
- The flexibility of the working schedule would influence the auto trips through the transport preference

4.2 BASIC APPROACHES

This study will use structural equation modelling (SEM) which can handle indirect and multiple relationships to do causal analysis.

As already applied in context role study (Franklin, 2012), a structural equation model of travel behaviour changes as a function of both demographic variables and contextual variables will be applied. The interactional effects between demographic variables and contextual variables, also between the factor in the same group themselves will also be tested in this study. Different from the previous study, the relationships of the trips and other affecting factors were evaluated separately for each year instead of taking the total difference of the trips. Since most of the commuting trips were more or less constant, taking the difference of trips might cause the missing of data and waste of useful information. In order to solve this problem, the two years were examined and estimated separately. The comparisons were done to the estimating results between each year.



The previous approach (left) and the approach applied in this thesis (right)

Figure 4-4 difference between the approaches

The structural equation modelling was performed by Lavaan package (Rosseel, 2012) in R. The P-test value indicates the model fit of the parameters. In order to see if there are differences between 2004 and 2006, bootstrapping was performed between each year at the iteration of 1000 times. If the 95% confidence bounds do no cross zero, it indicates a significant difference. Several parameters for the model fit were compared.

After the selection of the best models, the estimated effects were calculated more specifically. The total effects and indirect effects were calculated respectively.

4.3 INTRODUCTION TO LAVAAN PACKAGE

The Lavaan package (Rosseel, 2012) is an R-language based package to estimate various statistical models, including path analysis, confirmatory factor analysis, structural equation modelling and growth curve models (Rosseel, 2012). The structural equation modelling could be achieved by the package using three formula types: latent variable definitions, regressions and residual correlations. The models presented in this thesis used one latent variable: SES (social economic status). Other paths were drawn using regressions and correlations were stated. The result provided by the package has a nice layout of the basic factors we need: the number of iterations run before the model converged, the P-value and other criteria of model fit, the estimated coefficients of all variables, the Z-value and P-test results of the estimation and the covariance of the factors. The extensions of the package related to this thesis are the path diagram package and the Lavaan bootstrapping package. The path diagram package provides a nice layout and visualization of the causal and correlated effects and the bootstrapping package allows obtaining numerous coefficients, which can provide enough samples for the difference bootstrapping.

When estimating the effects of the dummy variables, the weight is represented by the sum of the coefficient and the intercept. Lavaan package allows fixed intercepts for each parameter. The model fit is performed twice, the first time was to gain the average intercepts between two years, and the second time was to fix the intercepts between the two years hence the coefficients of the dummy variable could be used to interpret the changing of the effects directly.

4.4 BOOTSTRAPPING FOR CONFIDENCE INTERVALS

Due to the complicity of structural equation modelling, the estimated coefficients have more complicated distributions than normal distribution. Hence, normal statistical test such as student t-test couldn't be applied due to the uncertainty of the distribution. In order to see if there is actual difference between two years, the statistical test for the difference between values in two years will be performed by bootstrapping. Bootstrapping is the method to sample estimated values by performing resampling manually in order to gain the distribution of the values. The basic way to construct the confidence interval is to take the

empirical quantiles from the resampled distribution of the parameters (Davison & Hinkley, 1997). Here the 25th and 75th quantiles were obtained to form the 95% confidence interval. If the interval doesn't cross zero, it means there is a statistically significant difference between two values.

Here in this case, two times of bootstrapping were performed. First one is to make sure the estimated coefficients in each year have significant effects, second one is to compare the difference between the two values in the two years, in other words, for making sure the differences of the two years were not zero. The first bootstrapping could use the extended package 'bootstrapLavaan'. For the second step, since the Lavaan package just provides one result of the estimated coefficients, the 'bootstrapLavaan' could be used to draw certain amount of coefficients to gain enough samples for the difference. Then the bootstrapping could be performed by programming again. The number of re-sampling is 1000 times for gaining the distribution.

5 RESULTS AND DISCUSSION

Based on the assumptions, 11 series of models were examined by Laavan package. Four distinguished models are presented in this thesis. All the estimated models were listed in Table 5-1.

Table 5-1 Summary of the hypothesized models

Hypothesized Model summary			
Model 0	all demographic - all contextual - all trips		
Model 1-6	Demographic factors -> SES, look into contextual factors		
	Model 1		SES -> SL card/ Access to car->Commute cross the cordon -> Trips
	Model 2		SES->Commute cross the cordon -> SL card/ Access to car -> Trips
		2.1	SES -> SL card -> PT trips, Access to car -> Auto trips
		2.2	SES -> SL card+ Access to car -> PT trips + Auto trips
	Model 3		SES -> SL card/ Access to car -> Trips
	Model 4		SES -> SL card/ Access to car/ Flexibility -> Trips
	Model 5		SES -> SL card/ Access to car/Commute cross the cordon -> Trips
	Model 6		SES -> Flexibility -> SL card/ Access to car -> Trips
Model 7-10	Combinations between demographic factors and other factors		
	Model 7		Gender factors
		7.1	Gender -> SL card/ Access to car -> Trips
		7.2	Gender -> SL card/ Access to car -> flexibility -> Trips
		7.3	Gender -> Commute cross the cordon ->SL card/ Access to car -> Trips
	Model 8		Age factors
		8.1	Age -> commute cross the cordon/ SL card/ Access to car -> Trips
		8.2	Age -> flexibility -> SL card/ Access to car -> Trips
	Model 9		Income factors
		9.1	Income -> commute cross the cordon/ SL card/ Access to car -> Trips
		9.2	Income -> flexibility -> SL card/ Access to car -> Trips
	Model 10		Combination of demographic factors

Models in **bold** were used in this study

Out of more than 10 models estimated, four models were selected by their model fit and significant results. The summary suggests that the interactions between contextual factors were found to be meaningful and significant. However, there were not reasonable results of significant findings in demography factor combinations.

5.1 BASIC MODEL

Model 1 presents the mediate, direct and indirect effects between all the demographic effects and contextual effects to the trips each year.

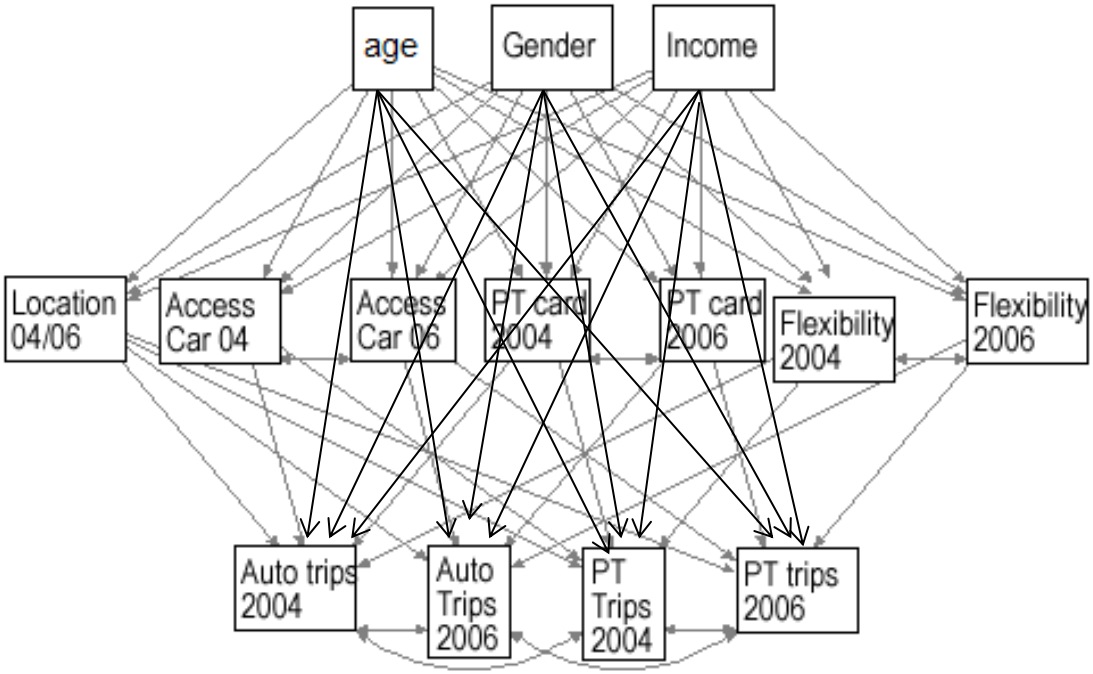


Figure 5-1 Path diagram of model 1

This model describes all the possibilities in the network vertically:

- Direct effects between demographic factors and the trip generation
- Indirect effects between demographic factors to the trip generation through the mediation factor of contextual factors
- Direct effects between exogenous variables (demographic factors) and endogenous variables(contextual factors)
- After all the estimation, the indirect effects and total effects between significant factors were calculated

Table 5-2 Model test results of model 1

Model Fit statistics of Model 1	
Number of iterations	223,000
Estimator	ML
Minimum Function Test Statistic	3057,243
Degrees of freedom	55,000
P-value (Chi-square)	0,000
User model versus baseline model	
Comparative Fit Index (CFI)	0,906
Loglikelihood and Information Criteria	
Loglikelihood user model (H0)	-87863,612
Loglikelihood unrestricted model (H1)	-86334,991
Number of free parameters	80,000
Akaike (AIC)	175887,224
Root Mean Square Error of Approximation	
RMSEA	0,095
90 Percent Confidence Interval	(0,092,0,098)
P-value RMSEA <= 0.05	0,000

Table 5-2 shows the model test of model 1. The P-value is close to 0 indicating a good model fit. The comparative fit index is close to 1, the high value also suggests an acceptable model fit in terms of the discrepancy of the data. The root mean square error of approximation is low, 9,5% of the data remained unexplained in the model.

From Table 5-3, several conclusions could be drawn:

Corresponding to the hypothesis, the location factor which indicated trips across the cordon started playing a more important role for auto trips in year 2006 than year 2004. According to the P-test, location wasn't significantly fitted in the model, which indicates that it wasn't a matter for the auto trips before the charging was introduced. However in year 2006, the location factor fitted in the model and the absolute value of the negative coefficient was larger, auto owners started taking the location factor into account and it decrease auto travelling.

For public transport trips, location factor wasn't fitted in the model either in year 2004 or year 2006.

Table 5-3 The direct effects of model 1

		Year 2004			Year 2006			bootstrapping confidence interval for difference in two years
	Variable	Estimated	Standard Error	P-test	Estimated	Standard Error	P-test	
Auto Trips	Intercept	1,49			1,490			
	Age	**-0,056***	0,018	0,002	**-0,047***	0,017	0,005	**(-0,01292 ,-0,01117)**
	Gender	**0,318**	0,053	0,000	**0,297**	0,050	0,000	(-0,001689,0,00335)
	Income	0,003	0,001	0,001	0,003	0,001	0,004	
	Location	-0,194	0,047	0,140	**-0,213***	0,044	0,000	**(0,01768 ,0,02266)**
	Car	**0,622***	0,108	0,000	**0,479***	0,100	0,000	**(0,09956,0,10774)**
	PT card	**-0,704***	0,043	0,000	**-0,608***	0,040	0,000	**(-0,12756,-0,12215)**
	Flexibility	**0,155***	0,045	0,001	**0,124***	0,041	0,003	**(0,03288,0,037606)**
Public	Intercept	0,59			0,59			
Transport	Age	**-0,019***	0,007	0,009	**-0,009***	0,007	0,227	**(-0,00056,-0,00051)**
Trips	Gender	**-0,208***	0,023	0,000	**-0,215***	0,023	0,000	**(0,00946,0,01176)**
	Income	0,000	0,000	0,321	0,000	0,000	0,863	
	Location	0,016	0,016	0,322	0,018	0,016	0,279	
	Car	**-0,094***	0,041	0,022	**-0,175***	0,041	0,000	**(0,00449 ,0,01057)**
	PT card	**0,308***	0,015	0,000	**0,298***	0,015	0,000	**(0,03976 ,0,04266)**
	Flexibility	0,029	0,015	0,053	**0,054***	0,015	0,000	**(-0,02432,-0,02247)**

Number of observations: 6054, Degrees of freedom: 33, Model P-value<=0,0001. Values in bold type indicate 95% confidence bounds do not cross zero. Values marked with * suggest a 95% confidence difference between two years by bootstrapping.

As for access to the car and the SL card, dummy values refer to the access to car/public transport. Reasonably, getting access to car suggests a positive effect for auto trips and vice versa for the SL card. Looking at the difference between the two years, there are significant differences between the two years in terms of the access to car. After the congestion charges were introduced, having the access to car plays less important role in the generation of auto trips. This means that there are other factors compensating the trip generation. This is the same for having a public transport card; the role of travelling by public transport affected less in year 2006.

Table 5-4 The direct effects of model 1 (sub model)

Contextual factors	Variable	Year 2004			Year 2006			bootstrapping confidence interval for difference in two years
		Estimated	Standard Error	P-test	Estimated	Standard Error	P-test	
Commute cross the cordon	Intercept	0,380			0,380			
	Age	**0,064***	0,002	0,000	**0,063***	0,002	0,000	**(0,001544,0,001766)**
	Gender	**0,028**	0,011	0,015	**0,029**	0,011	0,011	(-0,000596,0,000675)
	Income	0,000	0,000	0,575	0,000	0,000	0,079	
Access to car	Intercept	0,78			0,78			
	Age	**0,024**	0,001	0,000	**0,024**	0,001	0,000	(-0,00024,0,00038)
	Gender	**0,029***	0,003	0,000	**0,029***	0,003	0,000	**(0,00697,0,00759)**
	Income	0,001	0,000	0,000	0,001	0,000	0,000	
Public transport card	Intercept	0,56			0,56			
	Age	**-0,017 ***	0,003	0,000	**-0,014***	0,003	0,000	**(0,00426,0,0046)**
	Gender	**-0,101***	0,012	0,000	**-0,101***	0,012	0,000	**(0,00485,0,0061)**
	Income	0,000	0,000	0,196	0,000	0,000	0,252	
Flexible work hours	Intercept	0,49			0,49			
	Age	**-0,07***	0,003	0,000	**-0,069***	0,003	0,000	**(-0,0065,-0,0061)**
	Gender	**0,056***	0,012	0,000	**0,063***	0,012	0,000	**(-0,0097,-0,0082)**
	Income	0,005	0,000	0,000	0,005	0,000	0,000	

Number of observations: 6054, Degrees of freedom: 33, Model P-value<=0,0001. Values in bold type indicate 95% confidence bounds do not cross zero. Values marked with * suggest a 95% confidence difference between two years by bootstrapping.

As for public transport trips, the effect of flexibility was not significant as the P-value test suggested in 2004. However in year 2006, it started playing a role in the public transport. This might be due to the time-based congestion charge, the group of people who actually care about paying might pay attention to the time shifts. As for auto trips, the importance of flexibility changed but the effect seemed less, which is against the hypothesis. One explanation can be that high income people tend to have more flexibility at work, among which group they care less about the congestion payment. So there might actually be two different groups having different demographic factors involving. Hence, the direct effect of flexibility was more in public transport than in auto trips.

Table 5-4 shows the direct effects from exogenous to endogenous variables in model 1. Among all the demographic factors, the income factor was never

significant to all the contextual factors. For the gender factor, in general, the influences on contextual factors relating to auto trips were positive and vice versa to public transport factors. This result showed a same traditional view that males prefer driving than females. When checking the difference between two years, gender had no difference regarding to location, suggesting congestion charging hardly influence the auto trips in geographic level for gender difference. For access to the car and possession of long-term transport cards, there were slight changes between two years suggesting the trend of slight influence from congestion charging.

Table 5-5 The indirect effects and total effects of model 1

		Year 2004					Year 2006				
		a	b	IDE	DE	TE	a	b	IDE	DE	TE
Auto trips											
Age	Location	0,064	-0,194	-0,012			0,063	-0,213	-0,013		
	Car	0,024	0,622	**0,015**			0,024	0,479	**0,011**		
	PT card	-0,017	-0,704	0,012			-0,014	-0,608	0,009		
	Flexibility	-0,070	0,155	**-0,011**			-0,069	0,124	**-0,009**		
	total			0,004	-0,056	**-0,052**			-0,002	-0,047	**-0,049**
Gender	Location	0,028	-0,194	-0,005			0,029	-0,213	-0,006		
	Car	0,029	0,622	**0,018**			0,029	0,479	**0,014**		
	PT card	-0,101	-0,704	**0,071**			-0,101	-0,608	**0,061**		
	Flexibility	0,056	0,155	0,009			0,063	0,124	0,008		
	total			0,092	0,318	**0,410**			0,077	0,297	**0,374**
PT trips											
Age	Location	0,064	0,016	0,001			0,063	0,018	0,001		
	Car	0,024	-0,094	-0,002			0,024	-0,175	-0,004		
	PT card	-0,017	0,308	-0,005			-0,014	0,298	-0,004		
	Flexibility	-0,070	0,029	-0,002			-0,069	0,054	-0,004		
	total			-0,008	-0,019	**-0,027**			-0,011	-0,009	**-0,020**
Gender	Location	0,028	0,016	0,000			0,029	0,018	0,001		
	Car	0,029	-0,094	-0,003			0,029	-0,175	-0,005		
	PT card	-0,101	0,308	-0,031			-0,101	0,298	-0,030		
	Flexibility	0,056	0,029	0,002			0,063	0,054	0,003		
	total			-0,032	-0,208	**-0,240**			-0,031	-0,215	**-0,246**

a is the direct effects from exogenous to endogenous factors, b is the direct effects from mediating factors to dependent factors,
Values in bold suggest a 95% confidence difference by bootstrapping

Presented in Table 5-5, Figure 5-2 The effects from age to trips in model 1 and Figure 5-3 The effects from gender to trips in model 1 the indirect effects and total effects from demographic factor to trips through contextual factors were calculated. Income factor was taken out of the evaluation table since it wasn't fitted in the model. In general, the direct effects from demographic factors to the trips were weighted more than the indirect effects from contextual factors. However the subtle effects from the mechanism are inevitable.

As for age, it wasn't found there were indirect effects to trips through single context factors other than the direct effect to trips. As a result the total effects were found significant, but mainly contributed by the direct effects. It was less weighted, which means older people tend to change the driving habits less. There were significant differences in the indirect effects from gender to auto trips through mode choice. And the less weighted total effects indicated that male travellers tend to change the behaviour less than females in terms of the car access and SL card purchase.

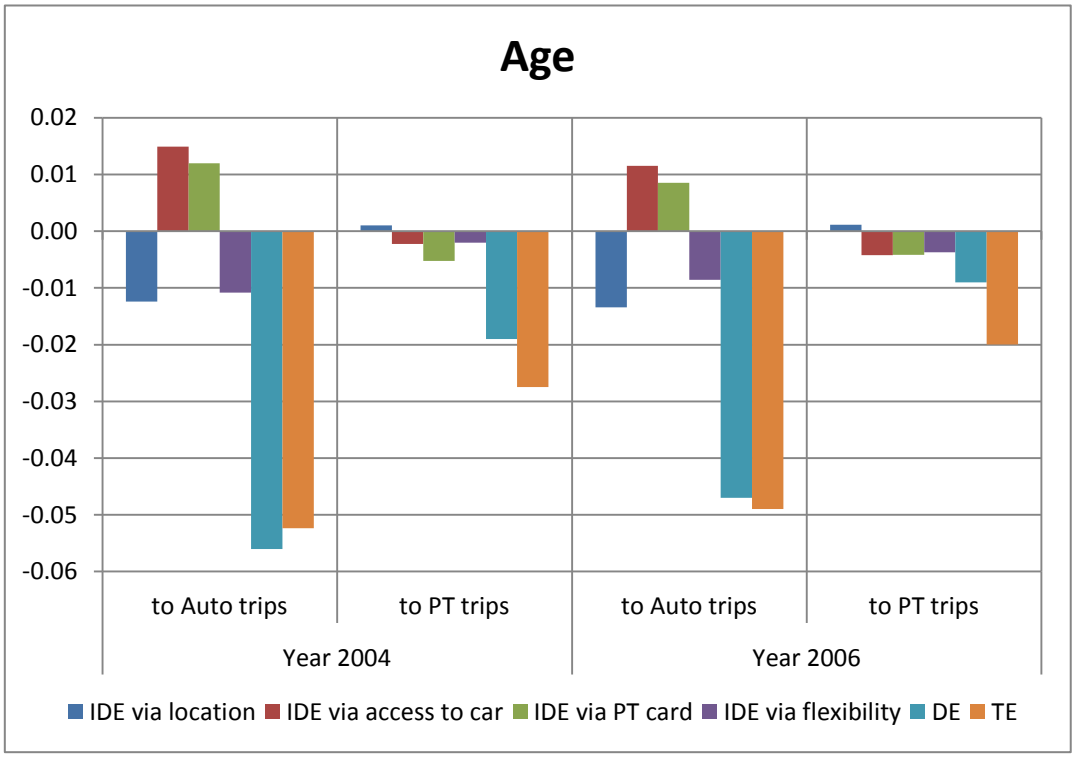


Figure 5-2 The effects from age to trips in model 1

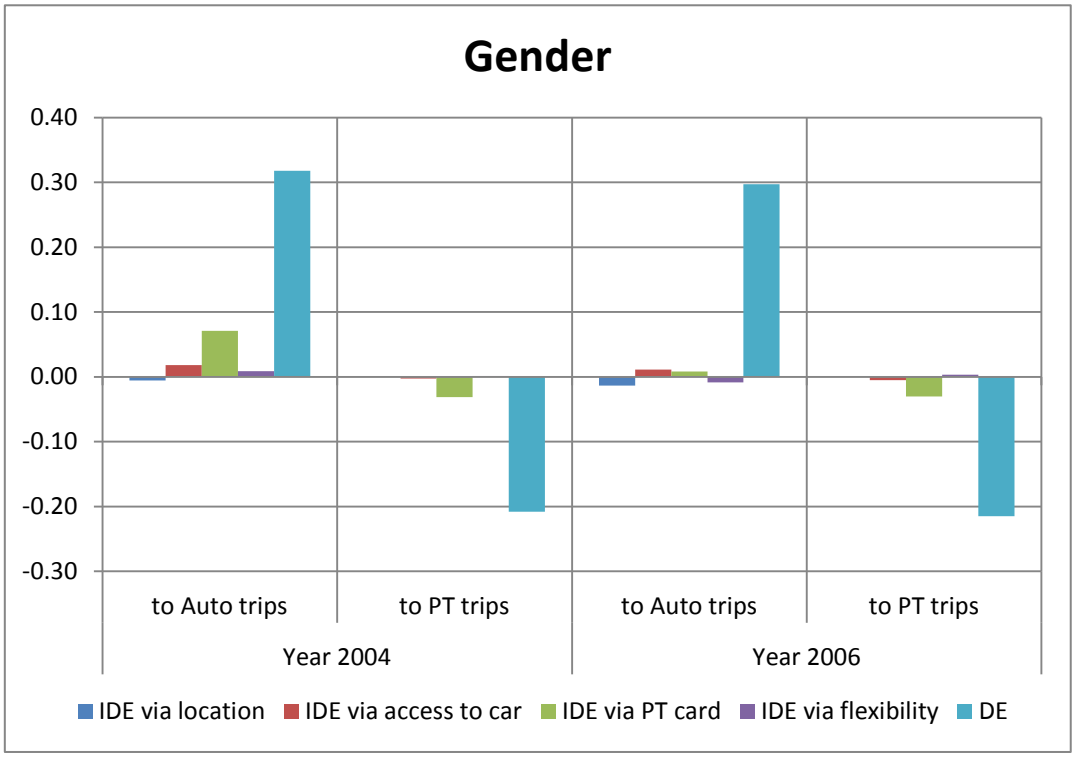


Figure 5-3 The effects from gender to trips in model 1

What's more, comparing these two factors, gender differs in the mode preference while age differs in location and flexibility. Males prefer driving than woman while old travellers have fewer tendencies towards changing behaviour through location and flexibility.

5.2 MODE PREFERENCE INFLUENCES RESIDENCE LOCATION

Model 2 presents the effects of two mediating factors – the mode choice and the location regarding to the cordon – to the trips in each year.

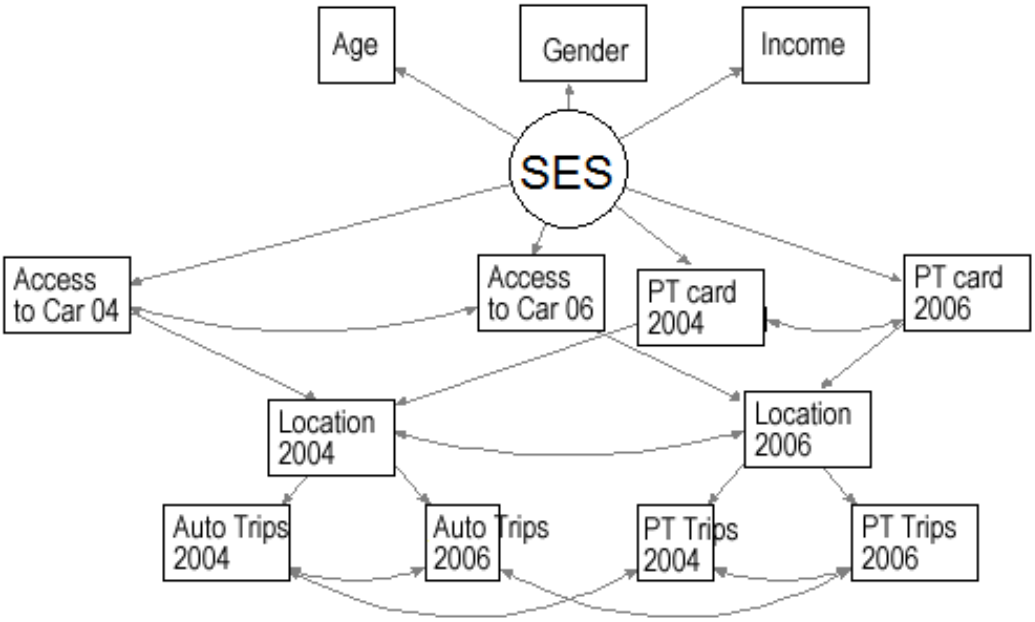


Figure 5-4 Path diagram of model 2, SES – Mode choice – location –trips

In model 2, the social economic statuses were combined into one latent variable: SES. This made it easier to test the interactive effects within the contextual factors group.

Here among the contextual factors, the home location is distracted from the access to the car and the SL card. According to the result in Table 5-6, there are differences between two years regard to the home location in both trips. In year 2006, commuting cross the cordon played a more important role in decreasing car trips. For public transport, it provided a positive effect for increasing public transport trips.

For the submodel, whether the mode choice preference will influence the home location choice can be seen. According to the hypothesis, the preference of mode would affect the residential location. Individuals who cannot get access to cars or incapable to driving are likely to live closer to public transport lines, on the

contrary, individuals who are apt to driving or enjoying the car mode are likely to live in places where it is convenient for driving. In terms of cordon congestion charging, not charging for inevitable commuting trips temps to be the preferred choice for car-preferring commuters. This factor was modelled by the factor of commuting across the cordon. According to the results, difference was found between the two years. In year 2006 access to the car had a larger effect to the home location. Together with the mediating effects through home location to the auto trips which can be seen in Table 5-7, it can be interpreted that the stable car users tend to prefer living in the place where they don't need to pay for the trips.

Table 5-6 Whole results of model 2

		Year 2004			**Year 2006**			bootstrapping confidence interval for difference in two years
	Variable	Estimated	Standard Error	P-test	Estimated	Standard Error	P-test	
Auto trips	Intercept	1,923			1,923			
	Location	**-0,223***	0,030	0,000	**-0,358***	0,028	0,000	**(-0.0071,-0.0025)**
Public Transport trips	Intercept	0,438			0,438			
	Location	**0,023***	0,012	0,045	**0,027***	0,012	0,020	**(-0.0037,-0.0022)**
Location(commute across the cordon)	Intercept	0,575			0,575			
	Access to car	**0,099***	0,010	0,000	**0,107***	0,010	0,000	**(-0.0074,-0.0046)**
	PT card	**0,074***	0,008	0,000	**0,072***	0,008	0,000	**(0,00078,0,00172)**
Access to car	Intercept	0,894			0,894			
	SES	**-0,026***	0,005	0,000	**-0,03***	0,005	0,000	**(0.0068,0.0167)**
PT card	Intercept	0,376			0,385			
	SES	**-0,107***	0,020	0,000	**-0,112***	0,020	0,000	**(0.0055,0.0154)**

Number of observations: 6054, Degrees of freedom: 33, Model P-value<=0,0001. Values in bold type indicate 95% confidence bounds do not cross zero. Values marked with * suggest a 95% confidence difference between two years by bootstrapping.

Surprisingly, for public transport trips; there were also significant changes of influence on residential places between the two years. A higher absolute value of coefficient of the indirect effects was observed in 2006 which indicated the deeper influence from location factor. The inconstant users of public transport who needed to cross the cordon have noticed the charges hence they shifted to use the public transport more often. The geographical choice could be interpreted as not only influenced by the car preference, also by the public transport.

Moreover, checking the indirect effects of endogenous variables (access to the car, SL card) to dependent variables (trips) via mediating endogenous variable (location) in Table 5-7,Figure 5-5 and Figure 5-6, the direct effects still played a more important role rather than the indirect effects through location. For auto trips, factors of access to car or SL card were all found to be significant. The total influence of access to car was less since the location effects had restricted it, and the same to the SL card.

Table 5-7 The indirect effects and total effects of model 2

		Year 2004					Year 2006				
		a	b	IDE	DE	TE	a	b	IDE	DE	TE
Auto trips											
Access to	Location	0,099	-0,223	**-0,022**			0,107	-0,358	**-0,038**		
car	total			**-0,022**	0,622	**0,600**			**-0,038**	0,479	**0,441**
PT card	Location	0,072	-0,223	**-0,016**			0,072	-0,358	**-0,026**		
	total			-0,016	-0,704	**-0,720**			-0,026	-0,608	**-0,634**
PT trips											
Access to	Location	0,099	0,023	0,002			0,099	0,027	0,003		
car	total			**0,002**	-0,094	**-0,092**			**0,003**	-0,175	**-0,172**
PT card	Location	0,072	0,023	0,002			0,072	0,027	0,002		
	total			0,002	0,308	**0,310**			0,002	0,298	**0,300**

a is the direct effects from endogenous to endogenous factors, b is the direct effects from mediating factors to dependent factors. Values in bold suggest a 95% confidence difference by bootstrapping

Displayed in Figure 5-5, there was significant difference between two years in indirect effects through location for auto trips; the deeper influence indicates the preference towards driving changed the behaviour through location choice. The same tendency was showed in Figure 5-6 that for auto trips, the indirect effects through location was significantly changed. However both of the figures showed no differences for public transport trips. It indicates that the travel behaviour changes from location only affect auto trips. The unstable driver shifted the mode to public transport through the choice of residential location.

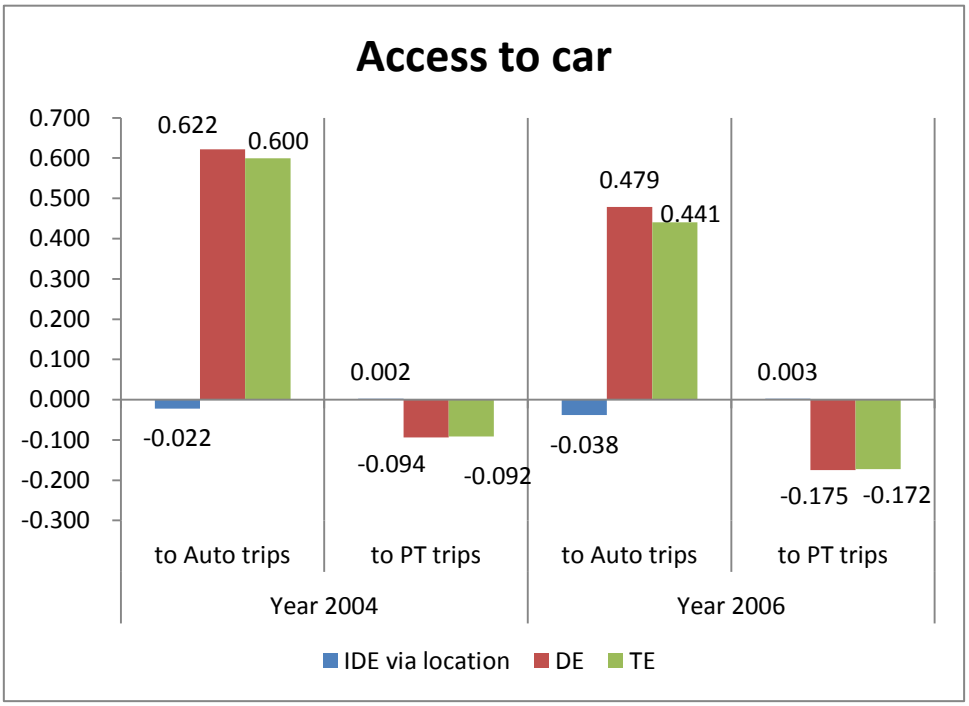


Figure 5-5 The effects from access to car to trips in model 2

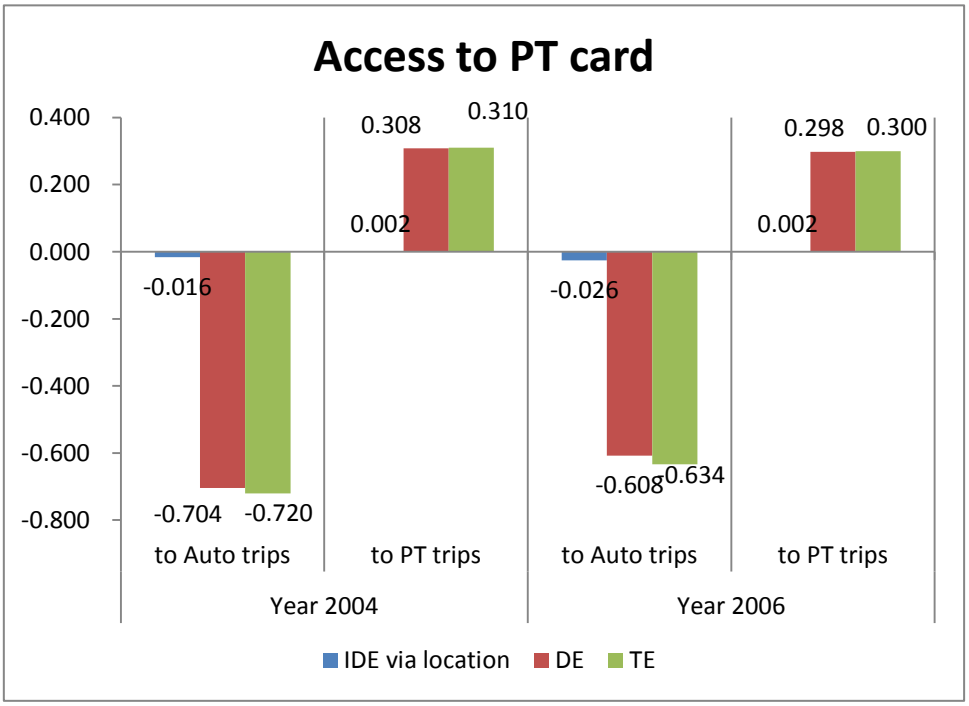


Figure 5-6 The effects from access to PT card to trips in model 2

5.3 RESIDENCE LOCATION INFLUENCES MODE PREFERENCE

Model 3 aimed to estimate the reverse effect of model 2. The casual effects of the two mediating factors were changed.

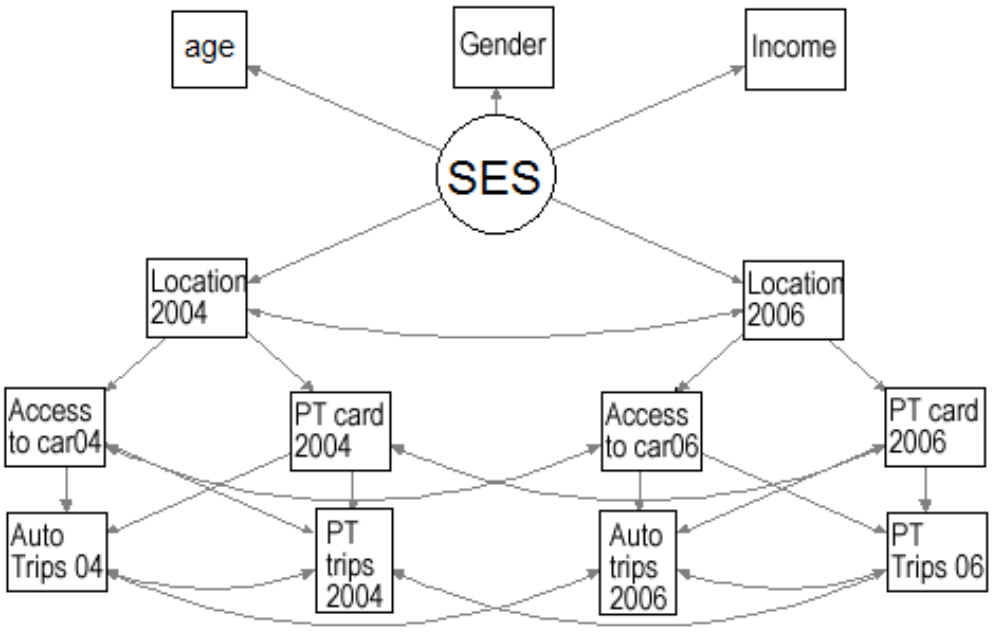


Figure 5-7 Diagram for model 3, SES – Location – mode choice – trips

As for the reverse effect between home location and the mode choice (the submodel in Table 5-8), the direct effects between car ownership and home location are not corresponding to assumptions. It was assumed that cross the cordon might have the effect on individuals to choose less the car mode. However there was no difference between two years. One explanation might be that the time of the implement of congestion charging was too short to influence the mode choice preference, or else, according to the relationship between car access and latent variable SES, high income class prefers driving and it can be assumed that people with wealth care less about the congestion fees. In accordance to the equity research result of congestion charges, the high-income social class is the most beneficial group from the congestion charges – if they live in the centre, which means they don't need to cross the cordon, they benefit both from the fee paying and the speed; if not, though they paid, they get the flexibility

and gain the saving of travel time. As a result, for people who already have access to car, the home location factor changed little behaviours for them.

Table 5-8 Whole results of model 3

		Year 2004			Year 2006			bootstrapping
	Variable	Estimated	Standard Error	P-test	Estimated	Standard Error	P-test	confidence interval for difference in two years
Auto trips	Intercept	1,350			1,350			
	Access to car	**0,767***	0,033	0,000	**0,604***	0,031	0,000	**(0.1059,0.1142)**
	PT card	**-0,714***	0,043	0,000	**-0,628***	0,040	0,000	**(-0.1237,-0.1181)**
Public Transport trips	Intercept	0,471			0,471			
	Access to car	**-0,165**	0,013	0,000	**-0,164**	0,014	0,000	(-0.0010,0.0043)
	PT card	**0,318***	0,015	0,000	**0,309***	0,015	0,000	**(0.0385,0.0415)**
Access to car	Intercept	0,891			0,891			
	Location	**0,082**	0,002	0,000	**0,083**	0,002	0,000	(-0,0006,0,00035)
PT card	Intercept	0,302			0,302			
	Location	**0,172***	0,007	0,000	**0,189***	0,007	0,000	**(-0.0016,-0.0006)**

Number of observations: 6054, Degrees of freedom: 33, Model P-value<=0,0001. Values in bold type indicate 95% confidence bounds do not cross zero. Values marked with * suggest a 95% confidence difference between two years by bootstrapping.

As for the total effects from location to auto trips through mode choice (Table 5-9), however, the change was significant. This means that adding the effects of access to transport card contributed to the location effects. Travelling across the cordon gave more negative effects on the auto trips.

Displayed in Figure 5-8, the location factor directly influenced the auto trips negatively however when going through the access to car, it was positive though less in 2006. This suggested that access to car influences most part of the auto trips but the location factor started dragging the influence down mildly.

Also, through the PT card possession to auto trips, the negative influence was less. It revealed that the residential place had fewer impacts for the purchase of the PT card. No conclusion could be drawn in this case using indirect effects. This suggests that the location might play a more complicated role than the simple indicator used here.

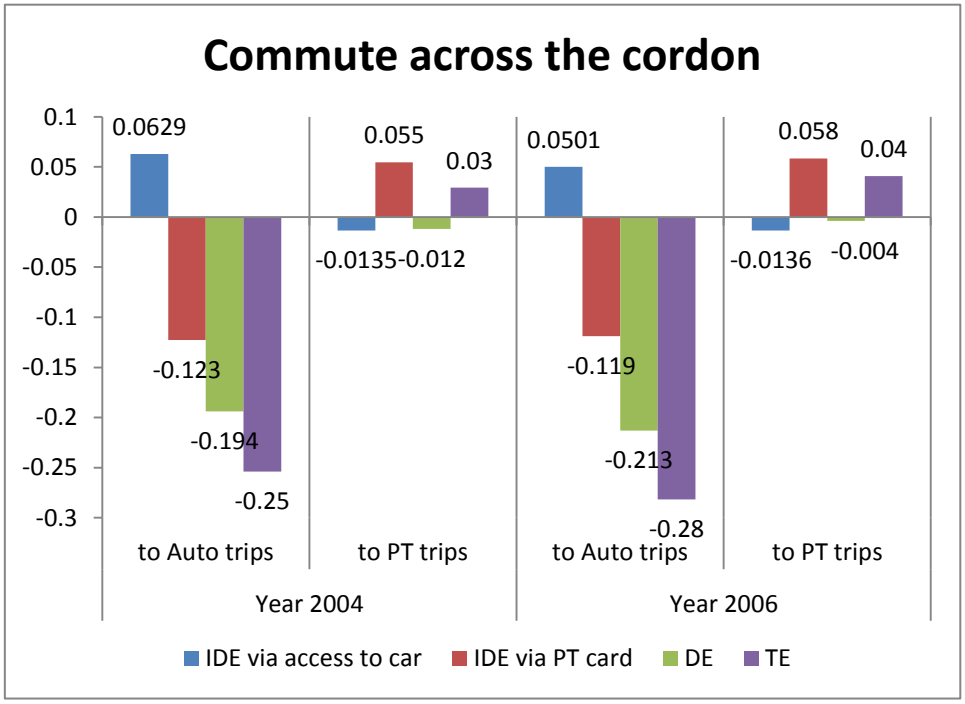


Figure 5-8 The effects from location to trips in model 3

Table 5-9 The indirect effects and total effects of model 3

		Year 2004					Year 2006				
		a	b	IDE	DE	TE	a	b	IDE	DE	TE
Auto trips											
Location	Access to car	0,082	0,767	**0,0629**			0,083	0,604	**0,0501**		
	PT card	0,172	-0,714	**-0,1228**			0,189	-0,628	**-0,1187**		
	total			-0,060	-0,194	**-0,2539**			-0,069	-0,213	**-0,2816**
PT trips											
Location	Access to car	0,082	-0,165	-0,0135			0,083	-0,164	-0,0136		
	PT card	0,172	0,318	**0,0547**			0,189	0,309	**0,0584**		
	total			0,0412	-0,0120	**0,0292**			0,0448	-0,0040	**0,0408**

a is the direct effects from endogenous to endogenous factors, b is the direct effects from mediating factors to dependent factors.

Values in bold suggest a 95% confidence difference by bootstrapping

5.4 THE COMPARISON BETWEEN MODEL 2 AND MODEL 3

Table 5-10 Model test results of Model 2 and Model 3

	Model2	**Model3**
Number of iterations	113,000	143,000
Estimator	ML	ML
Minimum Function Test Statistic	3592.746	3079.307
Degrees of freedom	54,000	52,000
P-value (Chi-square)	0,000	0,000
User model versus baseline model		
Comparative Fit Index (CFI)	0.886	0.902
Loglikelihood and Information Criteria		
Loglikelihood user model (H0)	-86161.582	-85904.862
Loglikelihood unrestricted model (H1)	-84365.209	-84365.209
Number of free parameters	50,000	52,000
Akaike (AIC)	172423.164	171913.725
Root Mean Square Error of Approximation		
RMSEA	0.104	0.098
90 Percent Confidence Interval	(0.101,0.107)	(0.095,0.101)
P-value RMSEA <= 0.05	0,000	0,000

In order to check the reliability of the two models, the commonly used measures of SEM model fit were applied for the two models.

Firstly, the P-value from Chi-Square was calculated. This is a fundamental measurement of fit in most of the model fit measures. The low P-values for the two model suggested good model fits. As for the CFI, as it was mentioned above, a CFI value higher than 0.9 is preferable. A better fit for model 3 was presented here while model 2 didn't meet the requirement.

The loglikelihood and information Criteria for both models were far more diverged from the test value, indicating good model fits in terms of the loglikelihood estimate. Model 3 was with lower values for Akaike information criterion (AIC), indicating a preferred model fit. That is, the unexplained variation between the explanatory variables and dependent variables was less in model 3.

Both of the root mean square errors of approximation (RMSEA) were low, but not low enough for reaching proper model fit. Model 2 with RMSEA higher than

0.1 suggests a poor model fit in terms of the discrepancy between the hypothesized model with optimally chosen parameter estimates.

To sum up, although model 2 indicated the tendency of the residential effects to mode choice strongly, the model fit compared to model 3 was poorer. The results from model 3 would be more believable but the strong relation suggested by model 2 is also not neglectable.

5.5 FLEXIBILITY INFLUENCES MODE PREFERENCE

This model describes the relationship between mode choice and trip generation through the flexibility.

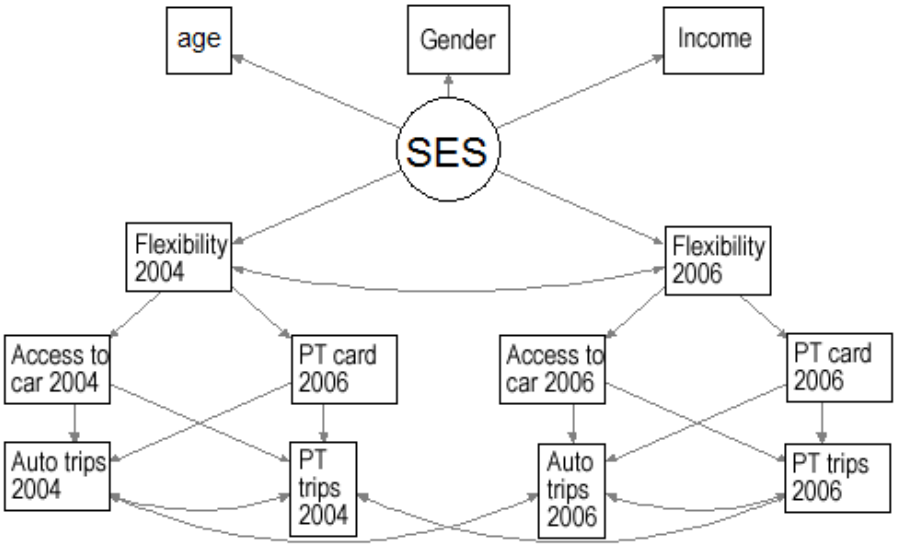


Figure 5-9 path diagram of model 4, SES – Flexibility – Mode choice – trips

Table 5-11 shows the model test results of Model 4. The P-value from Chi-Square suggests a good model fit from the fundamental way. However, the CFI is low due to in year 2004, the flexibility factor wasn't significant for the model so it showed a higher discrepancy. The loglikelihood and information Criteria for model 4 was far more diverged from the test value, indicating good model fits in terms of the loglikelihood estimate.

Table 5-11 Model test results of Model 4

Model Fit statistics of Model 4	
Number of iterations	114,000
Estimator	ML
Minimum Function Test Statistic	12202,177
Degrees of freedom	58,000
P-value (Chi-square)	0,000
User model versus baseline model	
Comparative Fit Index (CFI)	0,561
Loglikelihood and Information Criteria	
Loglikelihood user model (H0)	-86758,056
Loglikelihood unrestricted model (H1)	-80656,968
Number of free parameters	46,000
Akaike (AIC)	173608,112
Root Mean Square Error of Approximation	
RMSEA	0,186
90 Percent Confidence Interval	(0,183,0,189)
P-value RMSEA <= 0.05	0,000

Looking at the estimated sub model between flexibility and access to the car in Table 5-12, the flexibility has significant change in two years. In year 2004, according to the P statistical test, flexibility played no significant role for the car mode choice. But in year 2006, flexibility played a role for the car ownership. The estimated coefficient is a positive value, which means that it gave a positive direct influence for auto trip generation. The flexibility could help drivers avoid paying the most expensive charges in peak hours hence it positively influenced the auto trips. No significant changes could be found for public transport card ownership.

By checking the indirect effects to auto trips through the travel preferences in Table 5-13 and Figure 5-10, both of the trips were significant but against the assumption. It was assumed that drivers would care less about reducing trips if they had flexible working hours, but the result shows that the total effects of flexibility were less in year 2006. This is because the SL card ownership had bigger impact than car access on the trips; it proved again that certain group of people who were swinging between the two modes were forced to change the behaviour. Although flexibility did change some behaviour of the drivers, still it was not dominant.

Table 5-12 Sub model results for model 4

		Year 2004			Year 2006			bootstrapping
	Variable	Estimated	Standard Error	P-test	Estimated	Standard Error	P-test	confidence interval for difference in two years
Access to car	Intercept	0,890			0,890			
	work flexibility	0,005	0,006	0,408	**0,013***	0,006	0,003	**(-0.0139,-0.0119)**
PT card	Intercept	0,356			0,356			
	work flexibility	**0,132***	0,010	0,000	**0,140***	0,010	0,000	**(0.0024,0.0069)**

Number of observations: 6054, Degrees of freedom: 33, Model P-value<=0,0001. Values in bold type indicate 95% confidence bounds do not cross zero. Values marked with * suggest a 95% confidence difference between two years by bootstrapping.

Table 5-13 indirect effects and total effects of model 4

		Year 2004					Year 2006				
		a	b	IDE	DE	TE	a	b	IDE	DE	TE
Auto trips											
Flexibility	Access to car	0,005	0,535	**0,0027**			0,013	0,427	**0,0056**		
	PT card	0,132	-0,722	-0,0953			0,140	-0,634	-0,0888		
	total			-0,093	0,155	**0,0624**			-0,083	0,124	**0,0408**
PT trips											
Flexibility	Access to car	0,005	-0,175	**-0,0009**			0,013	-0,260	**-0,0034**		
	PT card	0,132	0,318	0,0420			0,140	0,305	0,0427		
	total			0,041	0,029	**0,0701**			0,039	0,054	**0,0933**

a is the direct effects from endogenous to endogenous factors, b is the direct effects from mediating factors to dependent factors. Values in bold suggest a 95% confidence difference by bootstrapping

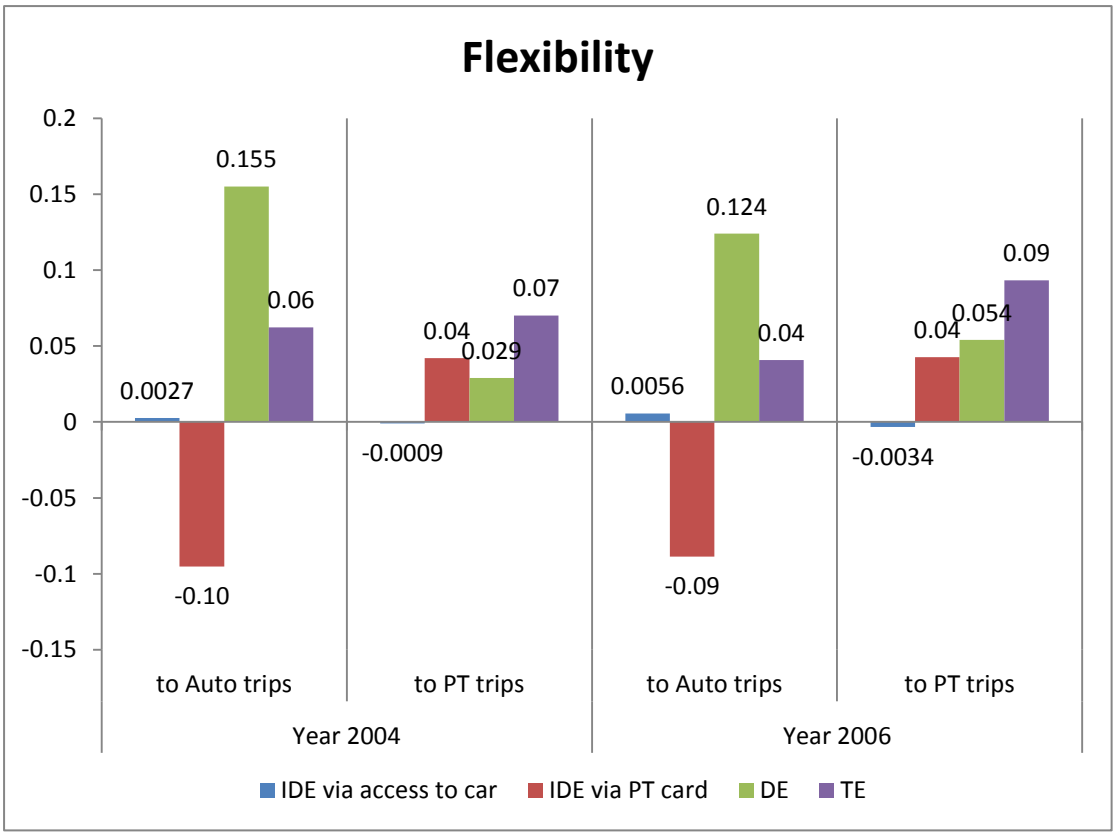


Figure 5-10 The effects from flexibility to trips in model 4

As it is shown in Figure 5-10, flexibility influences the trips more through public transport card than car driving. The indirect effects on public transport trips through card owner were almost equivalent as the direct effects. The effects of flexibility to trips in general are positive, but it was negative through public transport card to auto trips. Comparing to this, the changes for the indirect effects via access to car seemed less important but still notable.

To sum up, the flexibility positively influenced auto trips through the car owners after the congestion charging but not as strong as the influence to public transport card owners.

6 CONCLUSION

6.1 GENERAL CONCLUSIONS

According to the results, some of the hypotheses made before have been proved.

AGE AND GENDER INFLUENCE

Different demographic groups change travel behaviour through different mechanism, it was found in this study that different age groups differ in the location and flexibility and different gender groups differ in transport mode choice. Generally, males tend to change less than females in terms of driving; old people tend to change less than young people in terms of location and flexibility.

DEMOGRAPHIC FACTORS NOT SOLELY INFLUENCE

The changing of the behaviours was found to be more complicated that it was not just influenced by social economic status solely. Through mediating factors they showed more significant influence.

LOCATION MATTERS FOR AUTO TRIPS

After the congestion charging was introduced, commuting across the cordon started playing a role in reducing auto trips. Accordingly, the effects of car access and long-term public transport card ownership were less important than before since new factors were involved. When examining the interaction with mode choice by putting it as mediating factors, the total effects were found significant. As a result, the location matters for the individuals' travel behaviour both directly and through other factors.

INTERACTION EXISTS BETWEEN LOCATION AND THE PREFERENCE OF MODE

In year 2006 access to the car and SL card both had larger effects to the home location. The preference of mode choice has the tendency to influence the residential location choice in terms of auto trips. Reversely, though the changing of the auto trips mostly depended on the direct effects from access to car or public transport card, commuting across the cordon did make a little change for auto trips through the less access to the car. This influence is minor but still notable.

FLEXIBILITY PROMOTES TRIPS

In general, having flexibility in working schedule has positive effects on both types of trips. Corresponding to the hypothesis, flexible driving commuters cared

less about the congestion charging. However the total effects were mostly influenced by the indirect effects through the possession of the public transport card. The change of the total effects couldn't reflect the real trend of the changing since the scales of changing of the two factors were different. Individuals who were hesitating between the two modes were found to have higher sensitivity to the charging.

6.2 POLICY IMPLICATIONS

As it was mentioned above, transport policies are suggested to be progressive and improving recursively in order to give more benefits for disadvantaged group and put more burdens to privileged group. The studies in this thesis excavated more factors which might be taken into account when distinguish different groups both in terms of demography and context.

Firstly, the location choice is very important for setting up the charging places. It actually matters for travellers hence the location of the cordon might create new groups of beneficial group and disadvantaged group. The distribution of residence place and work place might be taken into account since the location chooses also involve in the behaviour change of the individuals. The same as the mode choice change, some groups suffer from choosing different residence locations.

Secondly, the flexibility of work schedule could be also taken into consideration. Congestion charging can redistribute the departure time for the groups of travellers who have flexible working hours. This reaches the goal of reducing congestion however also creates new beneficial group and suffered group. Those who don't have flexible working hours are forced to pay or change behaviours. When deciding the charging fee for time-based charging scheme, this factor should be considered.

Traditionally, when evaluating the beneficial groups in equity effects, only social economic status were taken into account in most cases. Middle-aged, rich males were always considered as the 'winner' of congestion charges. However, from this study, more combinations were found for forming privileged groups or disadvantaged groups by taking contextual factors into account. What's more, the results clearly stated the 'losers' of congestion charging were forced to

change the travel behaviour as well as lose the travel time benefits. The vertical equity effects should be put more concern on and investigated in detail.

The conclusions from this study can not only be applied in the future implementation of Stockholm congestion charging, but also in other cities when considering evaluating equity effects in order to understand by what mechanisms congestion pricing affects the equity. Based on the different conditions of the cities/countries, the same factors could be explored by the method used in this thesis.

6.3 LIMITATIONS AND FUTURE RESEARCH

There are several limitations in this thesis which needs further study. Firstly, the thesis presented only reasonable and significant models. As it was discussed in the results, the insignificance in car access variable still requires more specific research. More models between social economic status and the car access were estimated, but the model showed the same insignificant results. Due to the limited of time, all the parameters weren't fully tested.

Secondly, the indicating values in the model weren't decided in the best way. For example, the influence by public transport card access and the car access were offset in this study since the value indicating preference were the same. Since the two factors work in tandem and oppositely, the value should be defined inversely so the influence might be more significantly seen. As for social economic status, the categorical values could not fully represent the class of the people, for example lower values of age do not reflect lower likelihood towards dependent variables.

Thirdly, there were several limitations about the data. First of all, the data gained from 2006 were trial data; it could not be avoided that individuals might react differently at the introduction period and real period. The data could not represent the real change of attitudes in the long run. It has been a long time since the survey was carried out; the attitude of travellers might also have changed. Also, the data were simplified from the surveys; real data contain more details which can be used for more detailed studies. For example, the location factor was just simply represented by the crossing of the cordonThe survey data used in this study were filtered, only 6054 observations out of 77000 were used, they could not fully represent the whole population. But the conclusions and the tendency evaluated from the evaluation can be still meaningful.

In order to achieve the true fairness for the policy, further research should be done to distinguish the winners and losers among all, or even more factors in this study, taking all the limitations into account.

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