Bachelor Thesis Report

Conversion of automobile travel demand into public transport travel demand

Case study: Sydney

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Preface

This report is a result of a 12 week long internship at the Institute of Transport and Logistics Studies (ITLS) at the University of Sydney. Also with this report the last phase of completing the final stage of the Bachelor course Civil Engineering & Management at the University of Twente is completed.

In the first place I would like to thank Prof. David Hensher for giving me the opportunity to stay at the ITLS for this period and use the knowledge and expertise that is available at the institute. Also I would like to thank Dr. Sean Puckett for his supervision and support during my stay. It made my stay at the ITLS very pleasant.
Finally I would like to thank Dr. Tom Thomas from University of Twente for his critical input and support.

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Abstract

This report examines the effects of a free public transport policy combined with a pre-paid factor on conversion of automobile travel demand into public transport travel demand. The pre-paid factor includes psychological factor that occurs when individuals already have paid for the good and therefore wanting to use it. Survey is used to capture the hypnotized pre-paid effect. By comparing two similar cases the relative effect of the pre-paid policy is measured. The effects of free public transport policy and the pre-paid public transport policy are examined using TRESIS, a policy advisory tool that enables policymakers to evaluate impacts of transport and non-transport policy instruments on urban travel behavior and environment.

The main outcomes of the report are following: Free public transport (FPT) has a significant effect on modal shares. Also FPT affects the CO_2 emissions and travel times significantly however, these are less powerful than on mode switch. The effects tend to be greater on the long term making this policy very effective to influence modal shares, CO_2 emissions and travel times.

The measured pre-paid effect is not significant and therefore doesn’t exist on the short term. Therefore prepaid public transport is not an effective measure to influence the modal split, CO_2 emissions and travel time. The effects on the long term are unknown.

1. Introduction

Through an increasing car-use traffic emissions and congestion in urban areas are becoming more and more problematic. One of the solutions to these problems is the conversion of automobile travel demand into public transport travel demand [Fuji, 2001]. This implies persuading automobile drivers to use public transport. This is a very difficult task as the demand for public transport is very inelastic. Therefore a successful public transport system requires substantial government subsidy. Also, it is often the case that major investments in public transport don't have the intended effects. Is it possible to succeed in attracting more car users to public transport just by financing the public transport system differently?

This report will discuss a potential instrument to attract car users to public transport by an other financing approach then it is now the case.

2. Theoretical framework

Increasing wealth enabled us to travel with an incredible ease. Since a few decades we justly started to worry about the consequences of this comfort. The effects are twofold. On one hand the immense increase of road transport resulted in major environmental pollution. In the urban areas the busyness is large and the traffic flow is affected by traffic lights causing vehicles to accelerate and brake frequently. Especially here, the concerns are raised about the impacts of traffic emissions, like NO_x, CO and SO_2, on human health and the environmental quality in general. Moreover it is investigated that the road vehicles contribute significantly to the global CO_2 emissions, an important cause of the global warming [Nejadkoorki et al., 2008]. There has to be noted that in Sydney NO_x, CO and SO_2 pollutants are within the acceptable levels, however this doesn't mean that there is no space for improvement. CO_2 nevertheless is also in Australia on the rise. On the other hand the increase in road transportation causes congestion in urban areas. The cost of road congestion is estimated at $5109m per annum, with Sydney at $2080m the highest equivalent to $416 per person [Hensher 2006].

In the past years various ideas have been developed to reduce the traffic emissions and congestion in urban areas. In the next paragraph a promising measure consisting *variable user charge* will be discussed. At the end of this discussion a new idea of charging systems will be presented.

2.1 Variable and general user charges

As in the article of Hensher et al. (Hensher, Bain, & Stanley, 2008) is stated, congestion and emission charges are the most close to the ideal of *variable user charges*. Within this concept individuals pay based on their travel frequency, the frequent users pay more then not-frequent users. This concept is mostly concentrated on the private transportation (car, motorcycle etc.). The goal of these policies is to transform the private transport from *general user charges,* where the payments are not based on individuals travel frequency, to variable user charges, and in this way diminish the car use resulting in less congestion and emissions.
Transformation of private transportation to variable user charges can be achieved by policies like fuel prices, congestion charging, parking charges, carbon taxes etc.

Variable user charge ← Transformation of private transport **General user charge**

On the other hand there is public transportation (PT). As the congestion and emission charges on private transportation, more frequent use of PT can also result in less congestion and emissions. This is confirmed by virtually all analysts, they agree that indirect social and environmental benefits of public transport are also closely correlated with the level of public transport use [Pucher & Kurth, 1987]. By making public transport attractive, more individuals are persuaded on using it instead of the car. This concept can be seen as a reverse of the transformation of the private transport. By transforming the public transport from variable user charge (which is now the case as people pay based on their travel frequency) to general user charge, public transportation will truly be public and attract more users.

Variable user charge Transformation of public transport → **General user charge**

The general user charge can for example be accomplished by levying taxes for public transportation on all inhabitants in an urban area. The Sydney Travel Survey in 1991 shows a train share of 3.7% and a bus share of 4.3% for Metropolitan Sydney, what implies that there is need for improvements [Hensher, 2006].

As the discussion about reduction of traffic emissions and congestion is mostly aimed at private vehicles it is interesting to assess the impacts of measures that increase the modal share of PT through transforming the public transport from variable to general user charges, as described above.

In the next paragraph a pricing method is introduced that seems promising to accomplish the transformation of public transport from variable to general user charge.

2.2 Public transport pricing methods

The current pricing system for public transport is a mix of general user charges (subsidy) and variable user charges (fares). The revenues gained by fares are approximately 40% of the total operating cost for public transport [Pucher & Kurth, 1987], the other part is subsidized by the government, who generates money from taxes (Figure 1a). The people are paying the whole amount of the subsidy indirectly, not realizing this and not taking this into account when making a choice in which mode to chose. What would happen if the inhabitants of a big city's would receive an annually tax explicitly for public transport, making the public transport free to this area? A possible scenario is outlined in figure 1b. As Fujii et al. points out, the travel mode choice does not directly depend on the objective service level of a transportation system but on psychological factors such as beliefs, attitudes and habits. So by influencing the psychological factors the travel mode choice can be act on. In this case this doesn't only apply to prices (free fares) but to psychological factor of *already having paid* for the good and therefore wanting to use it. In this report we will call this hypothesized effect the *pre-paid effect*. This is confirmed by Schlag et al. [Schlag], who found a considerable effect of who is paying for the trip; the travelers who paid for their trip themselves appear to have a broader consideration – set.

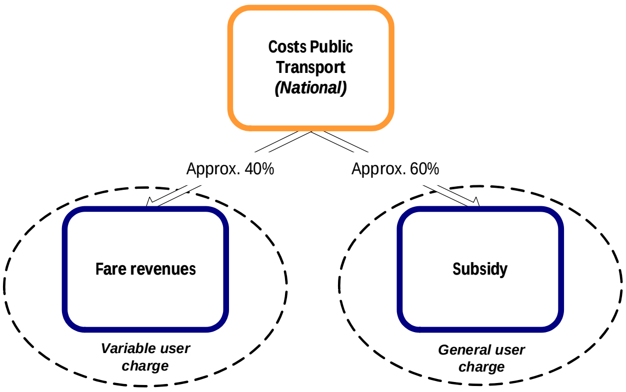


Figure 1a: PT structure now

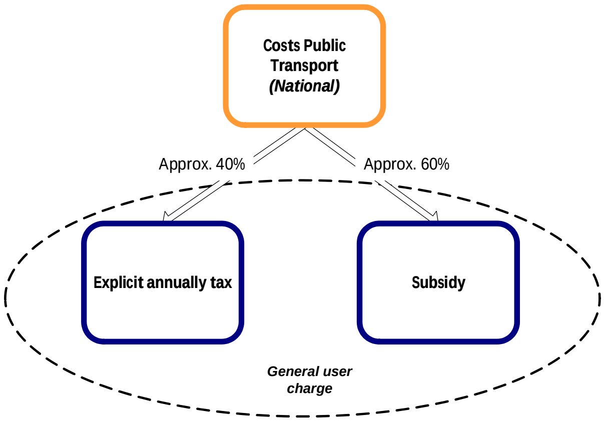


Figure 1b: PT structure with explicit tax

As this pricing method may provide interesting results on the modal choices made by the individuals it seem worth examining what the influence of such a policy really is. In the next chapter a research plan will be presented.

3. Research plan

In this chapter the research plan is presented. On basis of the examined literature a hypothesis is formulated. To test this hypothesis a set of research questions will have to be answered, and in which way the answers are gained is presented in the next chapter where the methodology of the research is described.

3.1 Hypothesis

When the inhabitants Sydney region receive an annually tax explicitly for public transport which enables them to travel for free in the city region, the modal shift from car to public transport will be significantly larger then it is now the case. Instead of creating disincentives for people by pricing movements of people by private vehicle, people are now paying for a possibility to travel without any limitations. An incentive is made to travel instead of not to travel (Figure 2).

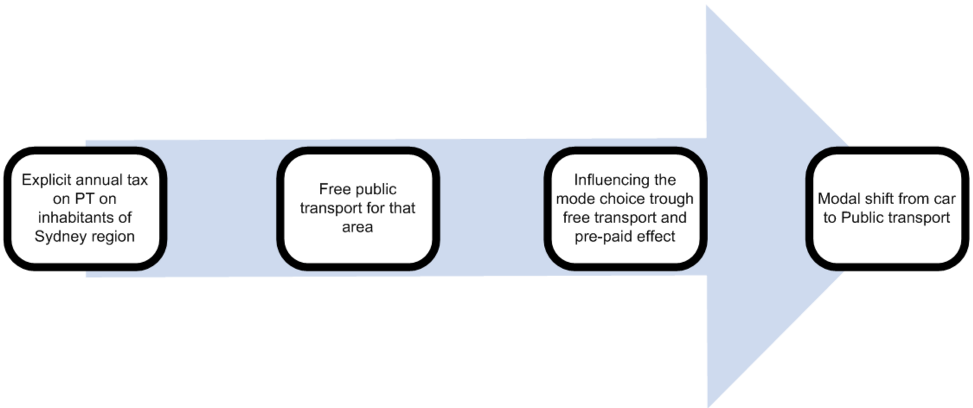


Figure 2: Modal shift to Public transport

3.2 Objectives

The objective of this research is to asses the influence of the described pricing policy on public transport on the modal shift from car to public transport, and in this way be able to make conclusions of the effectiveness of such a measure.

3.3 Research Questions

The questions that have to be answered in order to fulfill the objectives mentioned above can be subdivided in two parts:

Main question

What is the influence of the described measure where people pay taxes for the public transport explicitly, on the traffic emissions and congestion in urban areas?

Sub questions

1. What is the influence of free public transport in Sydney region on the modal split?
2. What is the influence of pre-paid public transport on the mode choice for inhabitants of the region?
3. What is the influence of the modal shift on the travel times in Sydney?
    i. Created by free public transport
    ii. Created by the pre-paid policy
4. What is the influence of the modal shift on the CO_2 emissions?
    i. Created by free public transport
    ii. Created by the pre-paid policy

4. Methodology

In figure 3 the research methodology is presented. The research is divided into three phases. The first phase is a literature research, which forms the foundation of the report. It focuses on the following three subjects: *pricing behaviors in public transport*, *free public transport* and the *pre-paid effect* which is hypothesized. Literature research forms the basis for the survey and is a very important tool in the means of how the results from the survey and TRESIS modeling are going to be interpreted. Furthermore this phase is used to elaborate the intended policy in a critical way comparing it's characteristics with the literature; this is done throughout the whole first phase. The second phase is the survey, whose main goal is to capture the hypnotized pre-paid effect. By comparing two similar cases the relative effect of the pre-paid policy is measured. The value of the pre-paid effect gained in survey is used in the third phase, TRESIS modeling. In this phase the influences of free public transport and pre-paid public transport on the modal shift and the correlated influences on travel times and CO_2 emissions in Sydney are estimated. Based on the three phases conclusions are drawn. In the next paragraphs the different phases are described in more detail.

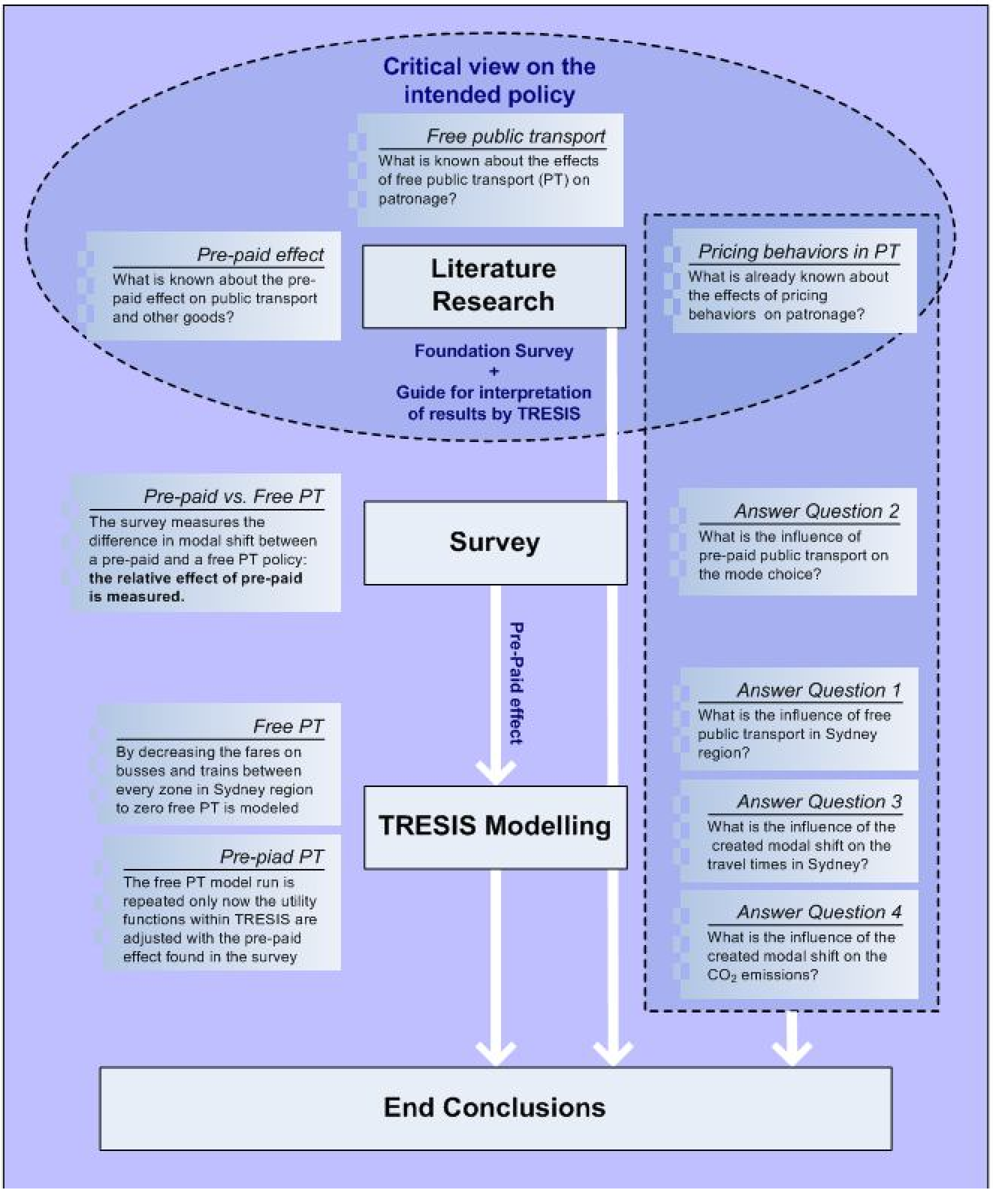
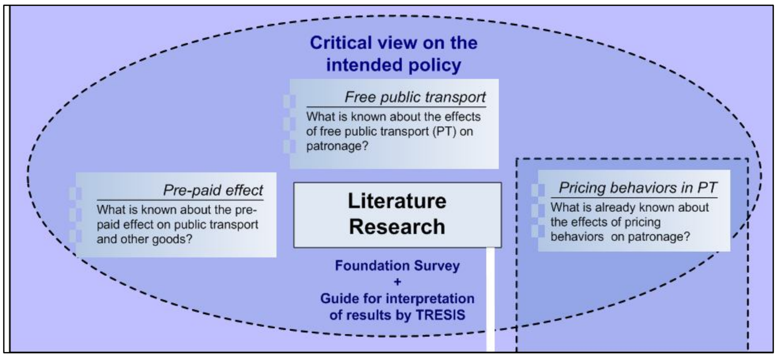


Figure 3: Research methodology

4.1 Phase 1: Literature research



The literature research starts with elaborating the relation between fare prices and patronage within public transportation. The main questions that are answered are: how the variation in public transport fares affects the patronage, in which cases and for which groups a decrease in public transport fares is most effective to achieve a patronage growth, how related modes influence public transport patronage and how the results gained from the survey and TRESIS-modeling have to be interpreted.

To explain on which grounds a mode is chosen by individuals the concept of utility is introduced. Basically the mode option with the highest utility outcome has the most chance to be chosen, where V is the outcome of the utility function of a specific mode (1.1).

$$P_{Train} = \frac{\exp(V_{Train})}{\exp(V_{Train}) + \exp(V_{Car})} = \frac{1}{1 + \exp(V_{Train} - V_{car})} \qquad (1.1)$$

The utility concept represents the attractiveness of an alternative, where the utility of a certain option is derived from the options characteristics, called attributes. The relative influence of each attribute is given by the coefficient β .

$$V_{Train} = \beta_1 + \beta_2 \cdot Time + \beta_3 \cdot Cost + \beta_4 \cdot Frequency + ... + \beta_x \cdot X \qquad (1.2)$$

In 1.2 several train attributes are given as an example. The coefficient without any attribute (β_1) is the *alternative-specific constant* representing the net influence of all unobserved or not explicitly included characteristics [Ortúzar & Willumsen, 2001].So elaborating the relation between public transport fare prices and patronage is in a sense elaborating the public transport attribute of cost with the outcome of the utility function. This theory is important as the modeling software TRESIS uses the same strategy to predict the mode choices by individuals.

This chapter is followed by a description of a specific pricing method where the fares are decreased to zero, causing free public transport. Understanding this specific pricing method is relevant as the policy that is investigated in this report (Pre-paid Public Transport – PPPT) and Free Public Transport (FPT) have very similar characteristics (Figure 4). In both cases ticketing is abolished and the people can travel with *zero marginal cost*. With zero marginal cost is meant that individuals don't require any additional costs to make one more public transport trip. The main difference is that the PPPT policy implies out-of-pocket-money from every individual in form of an *explicit tax* and FPT policy is fully subsidized resulting in no out-of-pocket-money. These similarities enable us to implement the PPPT policy as a veiled FPT policy in TRESIS.

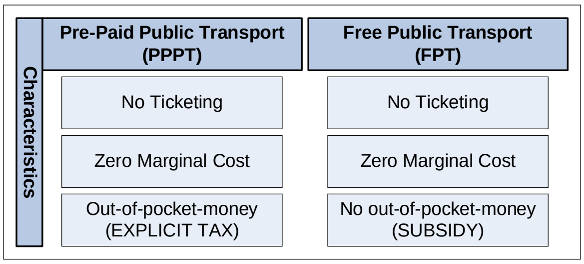
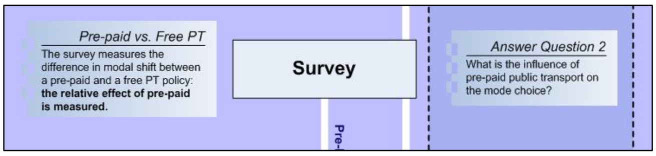


Figure 4: Prepaid and Free Public transport characteristics

Finally the literature research ends with discussing the hypothesized pre-paid effect in sectors where the effect is noticeable. How the utility functions are used to implement the pre-paid effect found in the survey (second phase) is described in paragraph about the TRESIS-Modeling methodology.

4.2 Phase 2: Survey



The survey gives a direct answer to research question 2 as stated in the research plan.
As described in the previous paragraph the PPPT-policy differs only on one point with the FPT-policy: the PPPT includes out-of-pocket-money whereas the FTP doesn't. In order to implement the PPPT-policy in TRESIS as a FTP-policy the influence of the hypothesized *pre-paid effect* has to be measured – the effect that occurs when individuals already have paid for a service and want to get the most value for their money by using the service much more then when they hadn't already spend their money on it.
The survey consists of two cases and for both cases the respondents are asked how many of their trips made by car they are willing to switch to public transport. In the first case the public transport is made totally free – FPT policy (totally subsidized by the government) whereas in the second case the public transport is governed by the PPPT-policy where the inhabitants of Sydney pay annually an explicit tax for public transport enabling them to travel with zero marginal cost. It is assumed that the difference between the outcomes of the two cases is caused by the *pre-paid effect*, whose magnitude is required for TRESIS modeling (Figure 5). The target group is inhabitants of Sydney region.

Amount of trips switched from car to public transport due to PPPT	-	Amount of trips switched from car to public transport due to FPT	=	Increase in switched trips due to Pre-Paid effect

Figure 5: The way how the Pre-paid effect is measured

Assumptions

To be able to measure the effect based on the two cases it is important to attend that only the cost is the varying variable. Although it is very likely for the level of service to vary with patronage, the survey cases present a level of service the same as it is now the case. The reason for this is the difficulty to predict the increase or decrease in the level of service due to yet unknown patronage change. Furthermore, it makes the survey questions more understandable for respondents as they can give answers based on the service level at this moment, which they are familiar with. The second assumption states that the pre-paid effect can be generalized on all car drivers. In other words, the individual and mode characteristics don't play any role on the magnitude of the pre-paid effect as they are equally presented in both cases. The assumption is that the policies are totally equal to each other except from the pre-paid effect.

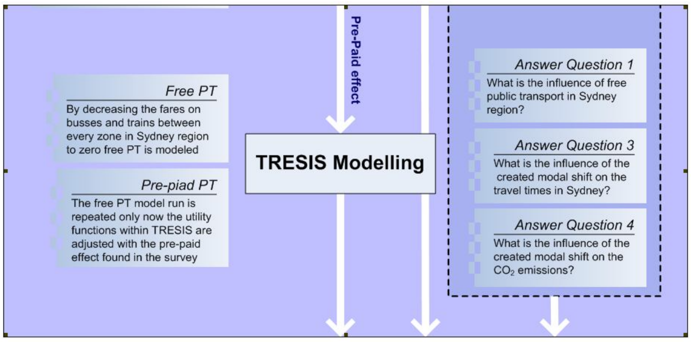
Analysis

The gathered data is analyzed using the software program SPSS 14.0. As in both cases scale rating questions are used the means of given answers are analyzed. The difference in the means expresses the pre-paid effect. The difference in means is interpreted as follows:

Example: Imagine that due to FPT people are willing to replace 10% of their trips on average. When asking the same question for PPPT they are willing to replace 12% of their car trips by public transport. This means $((\frac{12}{10})-1)\bullet 100 = 20\%$ increase in the amount of replaced trips due to pre-paid policy compared to the free public transport.
The results are analyzed in two categories. The first one compares the two policies on the total replaced car trips on the whole sample (i.e. 193 respondents). The other compares the two policies based on specific groups in the sample, for example car use frequency and car use activity.

The *significance* of the results is tested with the one-sampled T-test. The significance is tested on the test value equal to zero, as 0 implies no difference between the two cases – i.e. no effect is measured. A mail survey is applied to gather data with the staff of University of Sydney as the sample group.

4.3 Phase 3: TRESIS Modeling



TRESIS software is a policy advisory tool that evaluates impacts of transport and non-transport policy instruments on urban travel behavior and the environment. TRESIS can only estimate impacts on commuter travel. Within TRESIS it is possible to introduce several policies and predict their effects until the year 2017. For further detail consult Annex 10 in this report.

To estimate the shares of specific modes TRESIS uses the *concept of utility* as described before. Together with several databases, as 'behavioral model estimation database' and 'vehicle database', the mode choices estimated by the utility function form the groundwork for the estimates on CO_2 emissions and travel times in Sydney region. The utility functions for public transport modes are displayed below.

$$V_{Train} = -1.62898 - 0.025029 \cdot sc \cdot Time - 0.33682 \cdot sc \cdot Cost - 0.04174 \cdot sc \cdot Acces - 0.04174 \cdot sc \cdot Eggress - 0.011306 \cdot sc \cdot Freq. \quad (1.3)$$

$$V_{bus} = -2.03439 - 0.025029 \cdot sc \cdot mTime - 0.33682 \cdot sc \cdot Cost - 0.022043 \cdot sc \cdot Acces - 0.022043 \cdot sc \cdot Eggress - 0.011306 \cdot sc \cdot Freq. \quad (1.4)$$

Where, V is the outcome of the utility function. The coefficient without an attribute presents the *alternative-specific constant* representing the net influence of all unobserved or not explicitly included characteristics. The sc-coefficient, accompanying each of the attributes, is the stated choice for the attributes equals to +0.4.

The purpose of TRESIS Modeling is twofold (Figure 6). In the first place TRESIS is used to estimate how free public transport affects the modal split, and with that the travel times and CO_2 emissions in Sydney region. To achieve this two different runs are done in TRESIS. The first run decreases the travel costs for trains and busses to zero for each origin-destination zone. For the utility function it means that the attribute of cost equals zero resulting in the following utility function for trains (the same applies for the busses):

$$V_{Train} = -1.62898 - 0.025029 \cdot sc \cdot Time - 0.04174 \cdot sc \cdot Acces - 0.04174 \cdot sc \cdot Eggress - 0.011306 \cdot sc \cdot Freq. \quad (1.5)$$

In the second run, besides eliminating the cost, also the level of service is adjusted to a value that may be expected resulting from free public transport. These adjustments contain a frequency increase for trains and busses as more capacity is needed to cope with the patronage growth. Further the travel times for busses are adjusted because no ticketing means shorter loading times.

$$V_{Train} = -1.62898 - 0.025029 \cdot sc \cdot Time^{Adjust.(Bus)} - 0.04174 \cdot sc \cdot Acces - 0.04174 \cdot sc \cdot Eggress - 0.011306 \cdot sc \cdot Freq^{Adjust.} \quad (1.6)$$

In the second place TRESIS is used to estimate how prepaid public transport (PPPT) affects the modal split (i.e. travel times and CO_2 emissions in Sydney region). In this run the utility functions are adjusted by the pre-paid effect gained in the survey. This is done through calibrating the outcomes of utility function and thus the modal shares in TRESIS, to values found in the survey. The modal shares in TRESIS are varied by varying the utility function outcomes by indirectly adjusting the alternative specific constant.

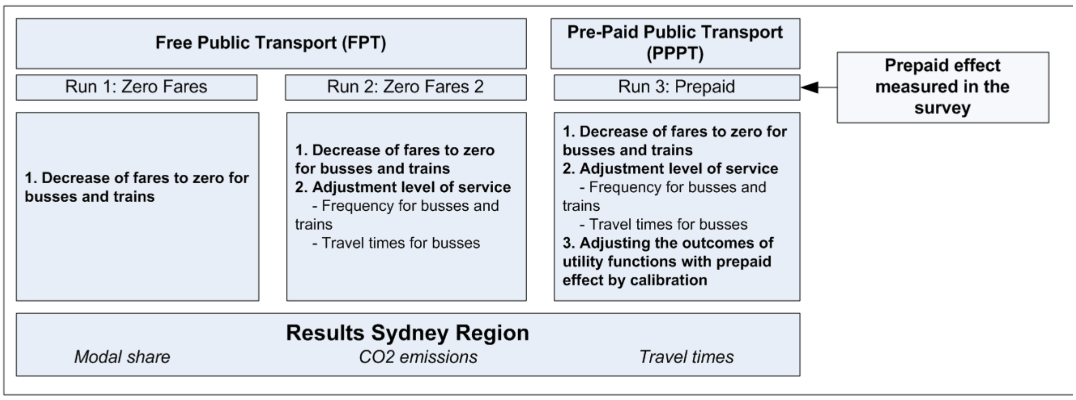


Figure 6: The TRESIS runs

5. Literature research

In this section the available literature concerning pricing systems for public transport will be discussed. The emphasis will be on the policy described in the previous chapter, so only elements that are a part of this policy will be considered.
The way in which we will setup and interpret the results of the survey and the TRESIS modeling depends on the knowledge we have about public transport pricing. So, even though this literature research won't give clear answers on the specific questions that we have defined in the research plan this section will form the basis of this report. Therefore in each chapter a link between the literature and the rest of the phases will be made.

The chapter will begin with defining peoples pricing behaviors when using public transport. As the considered policy includes that people will be able to travel with zero marginal costs the influences of free public transport on the ridership will be described. Finally we will look at the influence of the already-paid effect on people's behavior.

5.1 Public transport pricing behaviors

In this chapter peoples pricing behaviors concerning the use of public transport are examined.
Before focusing on these pricing effects the determinants of public transport use are described shortly. As the examined policy concentrates purely to influence individuals from the expenses point of view the other determinants won't play a role in this research. To examine the pricing behaviors of individuals firstly the price elasticity's of public transport are examined. In the next paragraph attention is paid on the direction of fare changes as there tends to be a difference in peoples behavior between fare price reduction and increase. The fare price changes don't only have an influence on the use of public transport but also on the use of other modes which are defined by cross elasticity of fare prices. As the reduction of car users by promoting the public transport is one of the objectives of the considered policy cross elasticity will be discussed. Finally differences between long and short term effects of pricing policy's and the possibilities of a modal switch to public transport according to examined literature are discussed.

5.1.1 Determinants of public transport use

The consumption of public transport differs with places and there are a lot of factors influencing the usage of public transport. These factors can be subdivided into two categories. Firstly, there are individual characteristics which are specific for each individual. These characteristics are for example: income, availability of a car(s), physical status etc. These characteristics are hard to affect.

Besides from the individual characteristics, the attractiveness of the different modes plays an important role when people have to choose which mode to use for a specific journey. The attractiveness of the alternatives is represented by the concept of *utility*. Basically the mode option with the highest utility outcome has the most chance to be chosen, where V is the outcome of the utility function of a specific mode (1.7). The utility of a certain option hereby is derived from the option's characteristics, attributes. For example the utility of a train trip depends among other things on the cost of train tickets, train frequency and the travel time. The relative influence of each attribute, in terms of contribution to the overall satisfaction produced by the alternative, is given by a coefficient β. The utility is often presented as a linear combination of variables (option attributes) (1.8). The coefficient without any attribute (β_1) is the *alternative-specific constant* representing the net influence of all unobserved or not explicitly included characteristics [Ortúzar & Willumsen, 2001]. These are for example characteristics that are hard to measure as comfort, safety, reliability, image and perception of a certain mode.

$$P_{Train} = \frac{\exp(V_{Train})}{\exp(V_{Train}) + \exp(V_{Car})} = \frac{1}{1+\exp(V_{Train} - V_{car})} \qquad (1.7)$$

$$V_{Train} = \beta_1 + \beta_2 \cdot Time + \beta_3 \cdot Cost + \beta_4 \cdot Frequency + ... + \beta_x \cdot X \qquad (1.8)$$

The option with the highest utility function outcome has the most chance to be chosen.

5.1.2 Demarcation

As described above the use of public transport depends on numerous factors. However the examined policy concentrates purely to influence individuals from the costs point of view. For this reason the other determinants will be left out of the scope of this research. This may be debatable when examining the pre-paid effect as it can be assumed that individuals who live where the accessibility and frequency of public transport is sufficient may be more affected by the pre-paid policy than those with an insufficient PT access and frequency. This problem is minimized by the fact that in the survey *relative effect* is measured. Under the same circumstances, holding every other attributes constant. In TRESIS this is not a problem as TRESIS reckons with most of those attributes.
Concluding, elaborating the relation between public transport fare prices and patronage is in a sense elaborating the public transport attribute of cost with the outcome of the utility function, holding all other attributes constant.

5.1.3 Price elasticity

When examining the influence of fare prices on the patronage of public transport the general law of demand plays an important role. The law of demand states that when prices decline consumption increases and the other way around, and measures this using elasticity's. Elasticity of a certain good is defined as the percentage change in consumption due to a one-percent price change, *all else held constant* [Litman, 2007]. So a high elasticity means that a small change in price causes a relatively large change in consumption. On the other hand when the prices have little effect on the consumption, the elasticity is low (the demand is then *inelastic*).

In general, for the public transport this means that when the fares rise the patronage will decrease and when the fares become cheaper the patronage will increase. The price of the fares affects directly the use of the public transport and is the perceived *marginal cost* – additional costs to make one more public transport trip. It needs to be mentioned that prices of travel modes are difficult to asses. The perceived marginal costs of car users are for example often biased as only the variable cost (fuel) are taken into account. The result is that for the same journey the costs of the car are underestimated compared to the public transit [De Witte, Macharis & Mairesse , 2008].

5.1.4 Public transport elasticity's

The elasticity's of public transport are difficult to assess as they tend to be influenced by numerous factors. For example the elasticity's vary by time of the day, mode type, trip type, income, place etc. Therefore it is not possible to define one price elasticity for public transport or for one specific mode. Because of that in this chapter we won't be describing all possible elasticity's as these, often different, numbers found in the literature won't add any value for the implementation of the policy described. The more important thing to know is, in which way the fare price elasticity's differ and why. Below a short summary is given.

Peak vs. off-peak

The trips made in the off-peak tend to be more sensitive for price changes. The cause for this is mainly the trip type made during theses hours [Paulley, et al., 2005]. The off-peak includes mostly personal trips which are much more flexible in time and space. On the other hand the trips made in the peak are mostly for work and education and work purposes and are therefore relatively fixed in time and space, resulting in a low elasticity on fares. These trends are confirmed by [Oum T.H., Waters W. G., & Yong J. S., 1990]. This may imply that also the pre-paid effect will differ between peak and off-peak.

Trip Type

As it is stated above the non-commuting trips, which are mostly made in the off-peak tend to be more sensitive to price changes than the commuting trips. [Litman, 2007] found that due to non commuting trips the off-peak elasticity for public transit is between 1.5 and 2 times higher than the peak elasticity. The same conclusion may be valid for the pre-paid effect, therefore in the survey setup a distinction is made between commuters and non-commuters. Also business trips paid by employers tend to have a very low elasticity [Paulley, et al., 2005]. This was also found by [De Witte, A., Macharis C. & Mairesse O., 2008] and may imply that if the costs are already made for a certain mode (pre-paid), the persons are not encouraged to switch to another mode. This would be a positive occurrence for the policy testing in this paper.

Income

People with low income tend to have a lower elasticity values because they often have no other choice of travel even though the fare prices increase. On the other hand the medium and the high income in most cases have a car at disposal which enables them to have alternative if fare prices increase [Paulley, et al., 2005]. But if the prices of public transport decrease they tend to be very difficult to persuade to switch from car to public transport. So the elasticity's in cases of increasing or decreasing fare prices may differ, this is discussed in the next paragraph. This group is therefore very difficult to manage when public transport is in question.

User type
The most users of public transport are transit dependent. By their income, driving disability, being students or age, they have no other choice but to travel with public transport. Therefore these groups are less sensitive to price changes [Litman, 2007]. On the other hand the discretionary riders are more price elastic and tend to be a big portion of our community. So the challenge to persuade these discretionary riders (who often have a car) may be a difficult one.

5.1.5 Fare reduction/increase

The elasticity's may differ as the prices either increase or decrease. The example described in paragraph 5.1.4 of medium and high income households who have a car at their disposal outlines this phenomenon very well. The literature may be a bit contradicting about this. Hensher and Bullock (1979) found for rail fares in Sydney, Australia that the fares are slightly asymmetrical, resulting in a fare elasticity of -0.21 when the fares increased and -0.19 when they were decreased. [Paulley, et al., 2005]. Dragay and Hanley (1999) also found that the demand is more sensitive to rising fares (short run -0.4; long run -0.7) then when they decreased (short run -0.3; long run -0.6) but in a larger magnitude [Litman, 2007].

In general it is accepted that the fare sensitivity is higher when the prices increase than when they decrease. However, the magnitude in which this occurs is not well known. This may have consequences for the increase in patronage due to the intended policy as the most fare price elasticity's are based on price increases than price decreases. Also Mackett and Bird (1989), who did a research on rail fares in South-east England, found that greater fare increases produce higher values of elasticity's. The effect of large fare decreases on the elasticity is nevertheless unknown [Paulley, et al., 2005].

5.1.6 Cross elasticity

In the last two paragraphs we considered influence of the fare prices of public transport on patronage. In that case the price changes have directly influence on the demand. In reality there are a lot of other goods that can influence the demand for a specific good. So the consumption of a good depends not only on its own price change but also on the price change in another, related good. For example, the increase in fuel prices for cars will lead to a decrease in car use and eventually result in an increase in public transport use. This is a cause of existence of a *cross elasticity* between car fuel prices and public transit. As we want to persuade the car drivers to use the public transit more often it is important to take the cross elasticity's between public transport and cars into account.

According to the research carried out by [Paulley, et al., 2005] public transport use is significantly sensitive to car cost. So if the car fuel prices rise, less people will use the car and more people will choose the public transport. However the opposite doesn't count – when the fare prices for public transport decrease individuals are not likely to switch from the car to public transport. The car use is almost independent of bus and underground fares, what may imply that the intended policy is not a good way to attract car drivers to public transport.

Also it should be mentioned that for attracting motorists to transit a relatively large fare reduction is needed since they are discretionary riders. The intended policy may cater to this tendency.

5.1.7 Long vs. short term effects

As we have seen, the elasticity's are dynamic and may change through time. Dargay and Hanly (1999) emphasized that the cross-elasticity of car use with respect to transit fares may increase over the long-run from almost zero to 0.3 and perhaps as high as 0.4. The regular elasticity's tend to be two or three times as large as the short-run [Litman, 2007]. Bresson, Dargay, Madre, & Pirotte (2003) agree with this and state that the adjustments of fare based policy's are relatively rapid, with the 99% of total effect realized within 6 years. Therefore in analyzing effects of price changes we might need to distinguish between short (1 or 2 years) and long (more than 5 years) -run elasticity values and take this into account for results which may only reflect the short-run.

As the results from the survey will be on the short run we will have to model TRESIS also within a year. The results may therefore be much smaller than if the policy would last for e.g. 5 years. In this case adjustments will have to be made.

5.1.8 Modal shift

The main problem of increasing the modal share of public transport is that the demand for PT is quite inelastic. This is especially the case in response to fare reductions Pucher & Kurth (1987). The cause of this phenomenon is partly a result of the fact that the transport costs make up a relatively small proportion of household expenditures.
The most congestion and the traffic emissions due to car use are created in the peak, and the most efficient way to reduce these is to reduce car use during that time. As the price elasticity is then at the lowest value, as we have seen in the previous paragraphs, it is especially difficult to persuade the peak car drivers to switch to public transport with fare reduction policy's. Also the fact that the commuting trips, who create the most congestion and emissions, have a low elasticity makes that switch hard to achieve.

However, switching people from their flexible, fast and beloved cars to mass transportation which lacks in these characteristics isn't going to be an easy task and as Bresson, et al (2003) state appropriate policy measures aimed at fare reductions can play a substantial role in encouraging the public transport and with that reduce the use of private cars. As appropriate policy's we may think at policy's that are not aimed at subsidy increase, like the one we are examining in this report. Several researches show that business and commuting trips paid by employers tend to have a very low elasticity [Paulley, et al., 2005 & De Witte, A., et al., 2008] and may imply that the costs play an important role in the mode choice.

Another important thing is that the most users of public transport are transit dependent. On the other hand the non-users, which have to be persuaded to become users, are mostly independent and have other transport options. Because of this difference a 'kink' occurs in the demand curve (Figure 7) [Litman, 2007]. This implies that small price decreases – for example decrease by 50% in price, will have the most effect on patronage for dependent riders. However this increase will be small as the dependent users seem to have low price elasticity's. On the other hand if the prices decrease with a much larger magnitude the discretionary (not dependent) riders will be encouraged to use the public transit. And as they tend to have a much higher price elasticity the increase per price may be much larger compared to the dependent drivers.

[Litman, 2007]

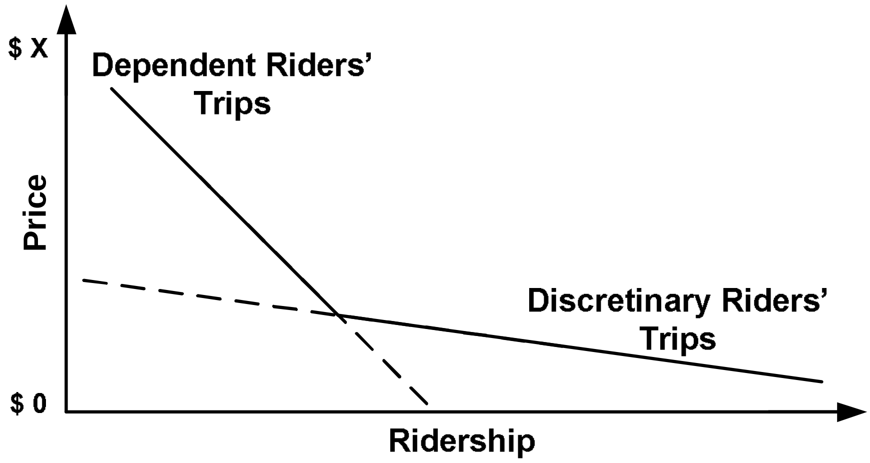


Figure 7: Kink in the demand curve

Therefore lowering the fares of public transport will have little impact on the patronage of PT and especially on the modal switch from car to public transit. Furthermore it generates revenue losses which result in higher subsidy. This can be defined as a ray of hope for the effectiveness of the intended policy.

5.2 Free public transport

The kink in the demand curve for public transport, described in the previous chapter, implies that a policy of large fare price decreases is needed to persuade the most harmful mode groups to public transit. This comes close to a widely discussed policy of totally subsidized and free public transport. In the next chapter this concept will be discussed as it contains similarities with the policy that is investigated in this report.

5.2.1 Concept

The concept of zero fare public transport is based on the fact that fare revenues at are just a small portion of the total operating cost of public transport systems. The rest (ca. 70%) is subsidized by the government who generates money from taxes. Three types of zero fare systems can be distinguished [Reynolds J.]: public transport that is free

1. for all passengers throughout the whole day
2. for certain groups throughout the whole day or certain periods
3. at certain places or times

Each of these types has advantages and disadvantages. For example, by making the public transport free for everybody the transit system may be congested due to people who switched from walking to PT, and therefore have less effect on the car users. The other two may not affect car users or won't have the advantages of fast and easy public transport. If the system isn't totally free ticketing will remain for some groups/times. This affects the simplicity of the system which can have great impact on the usage as we will se in the next chapter.
At this moment in the most cases it concerns free public transport of the last two types, although more and more cities, mostly with low population, make a switch to free PT for all passengers. Often we see free public transport for certain groups as elderly and students and at certain places and times like in the CBD of Melbourne. The problem of these policies is that they don't have the effect that is needed to decrease congestion en traffic emissions, because they are not aimed at car users.

Because the considered policy in this report has the most points of contact with the first type, we will be concentrating on that type.

The funding of free public transport can be established in various ways. Below a short summary is given and linked to the discussed zero fare systems:

Type of the system	Funding
1	Government revenue, specific levies or taxes on residents
2	Government revenue, specific levies or taxes on businesses or car users, universities & other educational institutions, private industry
3	Government revenue

Table 1: Ways of funding free PT

5.2.2 Advantages

In this paragraph the advantages of a zero fare system for all passengers throughout the day will be discussed [Reynolds & Waters].

- As the marginal costs of public transport are zero, people are encouraged to use the transit instead of other modes that do have marginal cost (car). This will lead in less car use, resulting in faster travel times and less traffic emissions.
- Free public transport results in faster boarding times since no tickets is needed and through this provides faster service. Also zero fare transport avoids equipment and personnel costs.
- The simplicity of a no-paying structure will attract more users as they don't have to bother about buying tickets.
- Passenger aggression may be reduced as they are claims that 90% of the aggression is related to refusal to pay the fare.

The main advantage of free public transport is that the people will be encouraged to use the public transit due to zero marginal cost.

Simplicity of free public transport

Pucher & Kurth (1987) examined the success of the Verkehrsverbund system in attracting more public transport riders. The system is currently being used in Germany, Austria and Switzerland. The Verbunds success lies for a great part in the uniform and integrated fare structure, which has improved the attractiveness of public transport in every Verbund. This was based on the fact that the ridership was discouraged by the complexity of previous zonal fare structures.

Also in Madrid an integrated fare system was introduced based on a travel card. This resulted in a patronage growth of 3.4% in the short-run and 7% in the long-run for the busses and 5.3% in the short-run and 15% in the long-run for underground transit. In Rome the ITS raised the patronage by more than 6% in two years [Abrate, Piacenza & Vannoni, 2008]. This was all achieved without any changes in the fare prices.

This phenomenon will also be caused by the considered policy and the effects of zero marginal cost, together with the property of integrated fare structure, on patronage may be much larger than we suspect.

5.2.3 Modal shift FPT

Useful literature about the effects of free public transport on the modal switch is rare to find. Large part is outdated as the policy was popular in the seventies when the car problems emerged. It lost its popularity due to its disadvantages and lack of courage by the politicians to implement such a policy. Also a part of the literature is based on theories on fare price elasticity's that we have seen in the previous chapter and may therefore be biased as zero-fares have more effects than only by elasticity's is explained. Nevertheless, below a short summary is given of the literature that might be useful.

De Witte, Macharis & Mairesse (2008) did a research on free public transport on commuters in Brussels and used data of 1276 commuters where 536 of them were filled out by car users and 740 by train users. He found that a 'company car' and 'cheap transport' are highly ranked by, respectively, car and train users. It appears that price plays an important role in their transport decision: not having to pay or only having to pay a part of the transport costs, because of a company car or train ticket remuneration, influences the transport decision [De Witte, Macharis & Mairesse 2008]. Results show that nine percent of the car users would be willing to make a modal shift when public transport is made free (Table 2).

[De Witte, Macharis & Mairesse 2008]

Willingness to switch	Service level now (%)	Removing the obstacles (%)
Yes, certainly	9	22
Maybe	39	49
No, certainly not	52	29

Table 2: Attractiveness of free public transport

39% are not sure and hesitate about making the switch and 52% of the car users knows already that he/she will not make the switch to public transport. Although 9% seems not much for a free consumption it can have large effects on the course of urban transport. As the most of the trips are by far made by car, 9% switch to public transport means an enormous increase in public transit use. Other thing is that when people are surveyed they tend to give answers what they would do if that policy would start tomorrow or in two weeks, so mostly in the short term. Therefore it can be expected that the switch may be much larger then the 9%, when we take into account the differences of elasticity's in short and long-run. From the 39% of the questioned people that answered not to be sure about their choice may exist of people who would switch to public transport on the long term.

Studenmund & Connor (1981) who did an evaluation on the results of several experiments that included elimination of bus fares in off-peak in Trenton, New Jersey and Denver (US) found that the measure did not had much effect on the car users. In general the experiment led to an enormous increase in patronage but the most additional travelers were originated from trips that would be made by walking en cycling.

[Reynolds] states that a zero-fare system is only a good way of increasing patronage if the passenger volumes and service levels are low. Next to this he states that car drivers perceive the marginal cost of the car use to be almost zero. This may mean that the public transport is only able to compete with the car if the marginal cost of using it is also zero.

5.2.4 Elasticity of Free Public Transport

Fare price elasticity's that have been examined in the previous chapter concern fare changes that are non-zero. So it may not be valid to assume that a 100% fare decrease will increase the demand by 33% (if E=0.33). This is the result of the law of diminishing returns that sates that elasticity decreases when the prices reach zero [Reynolds, year]. This is confirmed by Litman (2007) who emphasizes that this becomes significant when the price changes are more than 50%.
Furthermore the elasticity's may be affected by other advantages that free public transport brings along, like the simplicity of the system.

5.2.5 Problems

The fact that free public transportation isn't widely introduced is a result of some disadvantages that the measure poses. Below a summary of the main problems are discussed.

- As Studenmund & Connor (1981) already mentioned free public transport may result in overcrowded trains and busses due to switch of non-motorists to public transit and therefore may not affect the motorized modes. This is also named by Maxwell as one of the main problems of free PT.
- The perception is that policy isn't fair because some people's transport needs are not well-served by the public transit and still they have to pay the same charge as those who are being well-served. Furthermore some people will pay the bill fro PT through taxes and may never use it as they use other transport modes.
- Through the great patronage increase due to free fares a lot of money has to be spend on frequency and capacity expand to prevent overcrowding.

The problems described will also apply for the policy considered in this report. The intended policy doesn't differ much from the general zero fare policy funded by subsidy. However the policy may be seen as less unfair as only the people from the urban area, who are in the most cases well-served by the public transit, will be charged instead of everybody.
Another thing that is seen as a problem is the high costs of expanding the transit system. However, it is a choice that has to be made. Improving public transit isn't a cheap undertaking but otherwise the money would be spent on the car infrastructure that also cost a fortune.

5.3 Pre-paid effect

The considered policy consists of free public transport for which the inhabitants of Sydney Region explicitly pay an amount of money annually. The policy doesn't only aim to increase the patronage through making public transport free for this group but also to affect people's travel decisions through the *pre-paid effect*. This chapter describes the pre-paid effect. First a short introduction is given, followed by examples of goods where the effects of pre-paid are well known.

5.3.1 Introduction

Marginal costs (- additional costs to make one more trip) of car use are presumed to be close to zero, whereas the costs of public transport are not. The pre-paid effect is based on the fact that people are paying a large amount of the public transport costs indirectly through taxes, not realizing this and not taking this into account when making a choice in which mode to chose. As mentioned in the research plan we hypothesize that because of this effect people will be more encouraged to use public transport. As Fujii et al. (2001) points out, the travel mode choice does not directly depend on the objective service level of a transportation system but on psychological factors such as beliefs, attitudes and habits. So by influencing the psychological factors the travel mode choice can be act on. In this case this doesn't only apply to prices (free fares) but to psychological factor of already having paid for the good and therefore wanting to use it. This is confirmed by Schlag who found a considerable effect on who is paying for the trip; the travelers who pay for their trip themselves appear to have a broader consideration –set.

5.3.1 Already-paid effects, other goods

As there is a lack of literature about this phenomenon in the transportation sector a comparison will be made with other goods where the effects of pre-paid are well known. Below a summary is given about these findings – mostly done in the communication, health and hotel and catering industries.

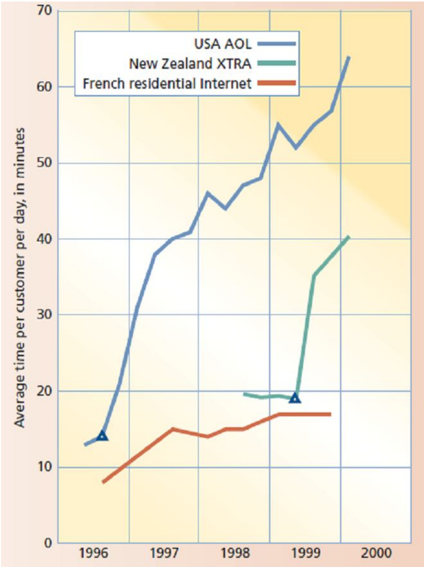
Internet

At the moment the predominant pricing plans offered by internet suppliers are flat-rate. This means that subscribers pay a fixed amount of money regardless of the usage. However when internet was introduced meter-based plans were used widely. One of the causes of the switch to a flat-rate plan had to do with the fact that users prefer the flat-rate pricing [Altmann & Chu, 2001].

Although flat-rate plans are economically inefficient because they result in over-usage (Figure 9) they predominate the usage-based plans. The main reason for this predominance is that people want to use internet whenever they want and usage-sensitive pricing tends to discourage this use [Da Silva, 2000]. One explanation is that consumers overestimate likelihood of using the internet enough to justify a flat-rate plan to probability of not using it enough to save money at a fixed price. Other thing is that people often intentionally buy more than they expect to use as they want to avoid the taxi meter effect and prevent negative surprises. According to Prelec and Loewenstein (1998) the taxi meter effect diminishes the joy of usage as the consumers experience an immediate 'pain of paying'. In flat-rate plans the linkage between usage and cost concerns is interrupted [Gerpott, 2009].

On the other hand consumers are willing to pay more for simplicity as they don't want to worry about the how much money they already have spend on internet [Odlyzko, 2000]. They just know that they have to put aside an amount of money for internet. It is proven by Gerpott (2009) that a significant share of the consumers prefers a flat-rate plans even if their invoice will be higher then when using a usage-based plan. This is confirmed by [Odlyzko, 2000].

[Odlyzko, 2000].



Odlyzko (2000) examined the growth of internet usage due to plat rate plans. He proved that a flat rate encourages demand. Arrows indicate the switch from metered to flat-rate pricing plan.

Figure 9: Growth of internet usage due to flat-rate plans

Although the trend described in figure 9 doesn't immediately imply that zero marginal cost attract more people to the internet, it does prove that the consumers are more positive about their product through using it much more than when the marginal cost were not equal to zero. Therefore a comparison with pre-paid policy in public transport may be a valid one. Next to this the fairness of the systems is comparable as in the internet sector 20% of users account for more than 80% of the traffic and so the frequent users are subsidized by the light users [Odlyzko, 2000]. The same is the case with phone subscriptions.

It has to be mentioned that there is some difference in the two systems. As internet subscribers have a choice whether they are subscribing to internet and with which plan, the inhabitants of Sydney will not. They will be included in the policy whether they like it or not. This may implies that the increase in demand due to zero marginal cost might not have the same magnitude. Also transportation enables people to participate activities and in the most cases it isn't an activity itself, which can imply that we can't speak about over-usage like in internet consumption. So for public transport the pre-paid effect will rather imply on attracting more users than over-usage by existing users.

Health insurance

The previous example considered activities that people enjoy to do or are at least not negative about. Therefore they are willing to consume more if the charges are flat-rate. As we mentioned before, transportation is often seen as a negative activity which enables people to undertake other activities. Health insurance has also a negative image as people rather don't want to be ill and get help of doctors, surgeons, dentists etc. Also health insurance has to be paid by everybody, irrespective of the use. Although there is a choice in which package to choose, health insurance can therefore very well be compared with the policy considered in this report.

Manning, Newhouse, Duan, Keeler, Leibowitz (1987) examined the relation between health insurance and demand for medical care. In a randomized experiment they compared groups with different percentage paid directly out-of-pocket. They found that the use of medical services responds to changes in the amount paid out-of-pocket. The expenses of free plan – no out-of-pocket costs (conventional health insurance) were 45% higher than those where the out-of-pocket costs were subjected to an upper limit. This can imply that people that had to pay the medical care out-of-pocket were more rational when using health care. In this case pre-paid insurance increases the use even though it is a negative activity.

With this we can conclude that pre-paid effect in insurance, and so on negative activities as well can have a great effect on the demand. In contrast to internet plans and phone subscriptions people are forced to take an insurance package.

All inclusive

Also well known examples where people already have paid for the activity are all inclusive vacations and all-you-can-eat restaurants. In the case of the vacations a fixed amount of money is paid for all activities including meals and drinks. These vacations are becoming more and more popular because once on the vacations people don't have to worry about their expenditures and the simplicity improves the usage because they don't have to pay. As in all-you-van-eat restaurants there is an incentive to over-usage [Courcoubetis & Weber, 2003].

5.4 Conclusions

As we have seen there are numerous determinants for public transport use. But as the marginal cost of car-use are presumed to be almost zero fare structures may be an important tool of attracting car users to public transport.

The policy is aimed at reduction of travel times and CO_2 congestion by persuading the car drivers to switch to public transport. But as we have seen car use is almost independent of bus and underground fares. The considered policy therefore may seem debatable. However, the long run effects are more promising and this has to be taken into account when evaluating the survey en TRESIS results.

One of the important advantages of the policy is that doesn't simply reduces fares creating a revenue loss but it drops the marginal costs to zero affecting the discretionary (not dependent) riders as the prices will be located below the 'kink' in the demand curve. Further we have seen that the considered policy is also aimed at the peak hours when the most car users are active and when it is most effective time to reduce the congestion and travel times. However, the price elasticity is then at the lowest point which makes the switch a difficult task. The same counts for the commuting trips. But it is not known what will happen with the elasticity when prices reach the zero. As the marginal costs of public transport for the first time will be lower then of the car, the results might be surprising.

The most free fare policies are not aimed at he most harmful mode groups and therefore not at decreasing congestion en traffic emissions. Whereas, the considered policy is. It will provide faster boarding times since no ticketing is needed and provide faster service. Also zero fare transport avoids equipment and personnel costs. The simplicity of the system may also play an important role. The results show that nine percent of the car users would be willing to make a modal shift when public transport is made free. Although 9% may seem not much, it can have large effects on the course of urban transport. Also result may be much larger due to long/short term effects.
On the other hand the policy is doubtful as it may persuade the walking and cycling trips, which result in overcrowded public transport system. Fairness of the policy is also an issue.

The policy doesn't only aim to increase the patronage through making public transport free for the area but also to affect people's travel decisions through the *pre-paid effect*. As we have seen, flat rates can have a great influence on demand of the described goods. Although, in the examples mentioned, it is sometimes difficult to asses if the increased demand will result in attracting new users or mostly will be an effect of over-usage. We can conclude that already paid effect has a positive influence on the image the people have of the good.
Further, according to the pre-paid examples we can conclude that people want to use that what they have paid for. Although the described systems and public transit differ, through which the assumption is slightly abstract, for public transit this might be an interesting fact. Therefore it is of importance to include this in the research.

The already paid effect will be examined through a survey aimed at car drivers. The setup of the survey will be described in the next section as well as the analyses of the results.

6. Survey

In the previous chapter a literature review was made on people's pricing behaviors when using public transport. As we have seen the considered policy consists of two main parts that may tend to influence people to use public transport instead of a car. The first part considers travelling with zero marginal cost. These effects will be measured using the simulation model TRESIS. The second part considers the pre-paid effect. As there is no literature about pre-paid effects in the transportation sector, a comparison was made with other goods, mostly done in the communication, health and hotel and catering industries. However, as the functions and characteristics of these activities may differ, it is invalid to use this information solely to draw same conclusions on the transportation sector. To measure these effects a survey is conducted.

This chapter starts by defining the survey objectives. Then a few assumptions are made concerning the link between the policy and survey questions. After that the design of the survey is explained. Subsequently, the survey questions will be discussed together with the results. After that the results are tested on their statistical significance. The chapter ends with conclusions and a discussion.

6.1 Survey objectives

As previously mentioned, TRESIS is only able to model a free fare policy for public transport. The main objective of the survey is to catch the effects of pre-paid public transport (PPPT) on people's travel behavior (i.e. answer on research question 2). With these results implemented in TRESIS the effects of a pre-paid policy on modal split, CO_2 emissions and travel times can be observed. Because the pre-paid policy in essence has the same characteristics as a free public transport (FPT) policy the survey compares the differences in behaviors between free public transport and pre-paid public transport. Only the cost vary, everything else including the other attributes are held constant.

Several questions are defined where the willingness to switch to public transport, the amount of trips per respondent are compared between the two policies. It is important to understand that the results of the findings of separate policies do not play any role in the modeling with TRESIS; only the differences between the policies are used (i.e. modal shifts found through the survey as a result of one of the two policies are not important, but the differences between them are).

The goal is to obtain the following specific data:

1. *Pre-paid effect*

The survey examines the pre-paid effect, which means: does the hypothesis stand that people want to use something they have already paid for in the specific case of the transport sector? So does the pre-paid policy have an effect on the usage of public transport?

2. *Modal switch*

The difference in the willingness to switch from car to public transport between the two policies. With these results TRESIS can calculate the effects mentioned above and in this way give answers on sub question 3 and 4.

3. *Over-usage vs. attraction of new users*

In the literature research, based on findings on other goods, it is hypothesized that an increased demand due to a pre-paid policy will lead to over-usage instead of attracting new users. The survey examines if this is also the case in the transportation sector.

4. *Attitude towards the pre-paid policy*

As it is important to know what people's attitudes are towards a policy when wanting to implement it, general opinions are examined. Attitudes may also play an important role for the answers given in the survey. When the respondents are positive they may give more satisfying answers than when they are negative.

6.2 Survey assumptions

As the intended policy contains a few differences between the reality and survey-modeling a few assumptions are made. These are presented below.

1. *In the survey the level of service will remain the same*

The possible increase or decrease in PT patronage is strongly connected with the level of service. It is expected that the service level will differ if public transport is made free. However what the exact difference is, is not quantified at this stage. Because it is difficult to obtain specific information about Sydney supposing a FPT or PPPT introduction, the service level is kept the same in the survey questions. This makes the survey questions more understandable for respondents, as they can give answers based on the service level at this moment – which they are familiar with. On the other hand, this implies that the generated results are only valid if effort is made to keep this level of service in the future. The cost of these efforts are calculated in the tax price described in annex 1.

2. The pre-paid effect can be generalized on car drivers

It is assumed that the pre-paid effect is the same for every car driver, regardless of his personal characteristics. This may seem invalid as travel distances, travel times and income may affect the travel choices. However, these characteristics are also present in FPT cases. As the survey only compares differences between the two policies holding all the rest constant. In this way the differences in growth of modal share found in the survey can be translated to the whole population in Sydney.

3. TRESIS takes account of missing characteristics

In the previous point we assumed that the pre-paid effect can be generalized on car drivers. However, for the travel choices caused by the whole policy (free PT and pre-paid PT) these characteristics (household car availability, home work distance, income, professional status, educational level, age, etc.) are essential and are taken into account when modeling with TRESIS.

6.3 Survey questions

The survey contains of 12 questions (Annex 8) which are presented on four pages on a website. Before the questionnaire an introductory text is presented to inform the respondents. As the survey is used to measure the differences between two similar policies, the questions for both situations are identical. To reduce the problems that occur due to habituation (i.e. which applies to a series of questions that all have the same answer choices, where people tend to give the same answers without really considering it [Survey Design, 2009] the related questions for each policy are presented on separate pages. This combined with the fact that the respondents are not allowed to return to filled pages also reduces the effect where people are affected by the questions later in the survey. To minimize this problem the survey should be taken twice on the same sample with enough time in between to make the answers more independent of each other. However, due to time limitations this was not possible.

The first seven questions are multiple-choice and are used to gather information about the sample and identify the representative sample. The questions are also used for analyzing different groups in the sample (i.e. distinctions in: car use frequency, car use activity, public transport use activity and public transport availability). Questions eight to eleven are used to compare the two policies, where questions eight and nine consider free public transport (FPT) and questions ten and eleven consider pre-paid public transport (PPPT). Both policies were compared on the amount of car trips that the respondents were willing to replace by public transport (scale answers) and on the total additional amount of trips (multiple choice).Question twelve is used to examine the attitude of the respondents towards a pre-paid public transport policy.

6.4 Survey design

For this research a web survey is used containing a total of twelve questions, eleven multiple choice/rating scales and one text open-ended question. In total 255 responses were gathered of which 193 were valid for analysis. The largest proportion of respondents, approximately 80%, consists of members of the ITLS Seminar Series Invitation List at the University of Sydney. The link of the survey website was sent via e-mail. The other 20% of the sample consists of visitors of the web log *Western Sydney Public Transport Users*, which was made available by a member of the list mentioned above. Before sending out, the survey was tested on a small pilot sample within the Institute of Transport and Logistics Studies.

From the eligible responses each lived and/or worked in the Sydney area described in annex 2&3, was between 18 and 65 years old and had a car at his/her disposal. 52% of the sample used the car frequently (i.e. more than once a day and once a day) the other 48% didn't used the car frequently (i.e. less than once in a few days). 42% of the respondents used their car for travelling between home and main work place (i.e. commuting) whereas the rest were used for other activities, the majority of which was for recreation and shopping. The largest part of the sample lived close to a public transport stop (60%); the rest lived more than 500 meters away from a PT stop.

The respondents were allowed to fill in the survey only once and it was not possible to return to questions to adjust their answers. The last restriction was put in place because the questions about the two policies were very similar and it was desirable to avoid respondents updating answers relating to the first policy, based upon exposure to the second policy. The responses were gathered for almost three weeks.

6.5 Results

In this section the results of the survey are presented. The gathered data is analysed using the software program SPSS 14.0. Through 'Contingency tables' and 'Compare means' functions, the data about the amount of car trips replaced by public transport and the total additional amount of trips were analysed. In both cases it is looked at the means of given answers as both questions considered a type of scale rating.

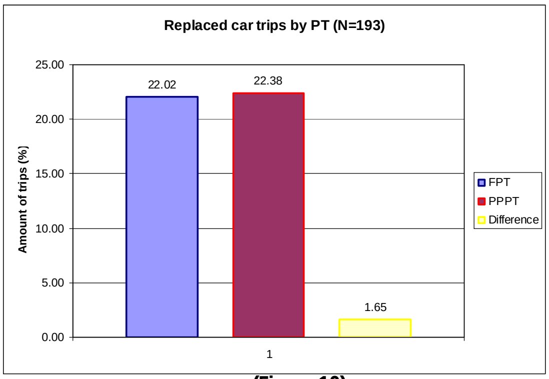
The means of each question obtained from the both policies are compared with each other. **Example:** Imagine that due to FPT people are willing to replace 10% of their trips on average. When asking the same question for PPPT they are willing to replace 12% of their car trips by public transport. This means $((\frac{12}{10})-1)\bullet 100 = 20\%$ increase in the amount of replaced trips due to pre-paid policy compared to the free public transport.

First the effects of a pre-paid policy will be examined, where we consider the willingness of people to replace their car trips by public transport. After that we confirm whether the policy has an influence on the total amount of trips made.

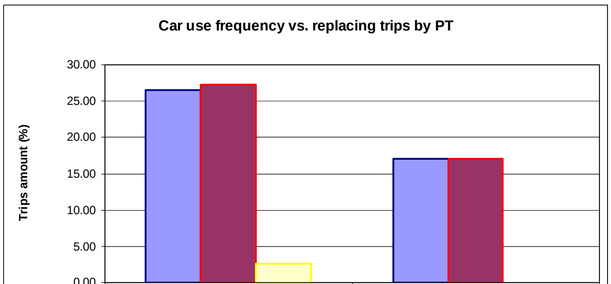
6.5.1 Replacing car trips by public transport

It is expected that people are willing to switch more car trips when a pre-paid policy is in force. In the hypothesis we stated that people will be influenced by the policy because they will want to use something they have paid for, which is confirmed in part by the literature.

According to the survey there is 1.65% more car trips replaced by the public transport due to PPPT compared to the FPT **(Figure 10)**. This confirms the hypothesis that people may be affected by a pre-paid policy. However, the conclusion should be treated with care as the differences between the policies are small.



(Figure 10)

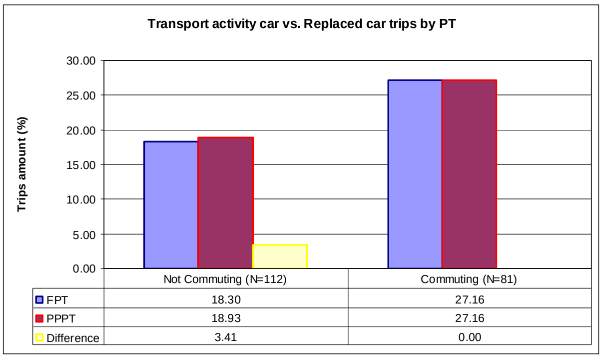


	Frequent car users (N=101)	Not-frequent car users (N=92)
FPT	26.53	17.07
PPPT	27.23	17.07
Difference	2.61	0.00

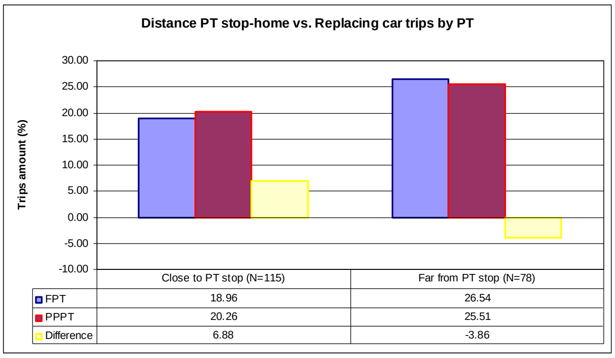
(Figure 11)

When we zoom into specific respondent groups it reveals that people who use their car frequently (e.g. once a day, once in a few days) are more willing to switch their trips by public transport than those who drive car infrequently (e.g. once a week, once a month) **(Figure 11)**. This last group is essentially unaffected by the policy.

The results show that people who use their car for commuting are not affected by the pre-paid policy **(Figure 12)**. On the other hand people who use cars for other activities than commuting tend to be compliant by the policy and are much more willing to replace their car trips by public transport than commuters. This observation can be explained by the relatively low price elasticity of commuters. As we have seen in the literature. Commuting trips are mostly made in the peak and tend to be relatively fixed in time and space. The non-commuting trips on the contrary tend to be much more flexible in time and space and therefore more sensitive to price changes.



(Figure 12)



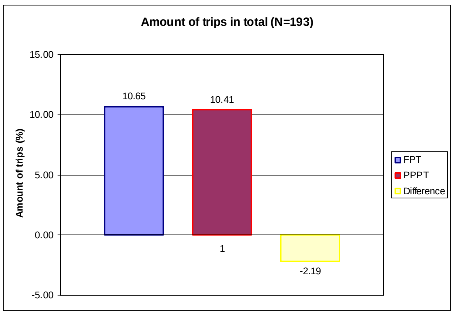
(Figure 13)

People close to public transport stops are more affected by the policy than those who live far away from them **(Figure 13)**. Those who have easy access may be more positive about the introduction of the policy and therefore are easier influenced by the fact that they already have paid. That the attitude towards the policy has influence on the results is clear when we look at tendencies of people who live far from a PT stop. They tend to replace less car trips with a pre-paid policy than they would have with free public transport.

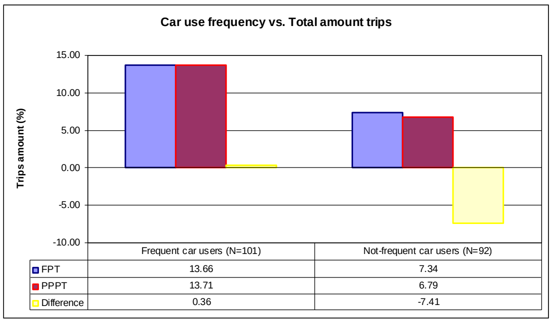
6.5.2 Total amount of trips

In the previous paragraph we have seen that prepaid public transport attracts new users (i.e. car users who switch to public transport). The literature showed that flat-rate plans, which can very well be compared with a pre-paid system, lead to over-usage. In this paragraph, results are given for the case of transport. Respondents were asked how many extra trips in total they would make due to the pre-paid policy. As the policy concentrates on public transport it is assumed that these extra trips are all made by public transport.

The survey shows that due to PPPT there are 2.19% less trips in total made compared to the FPT **(Figure 14).** Jet again the differences are very small. This is a surprising outcome because it is assumed that the policy would result in more over-usage, as we have seen with internet and phone subscriptions.



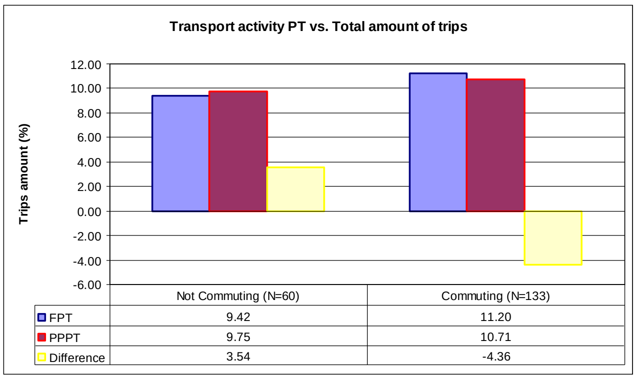
(Figure 14)

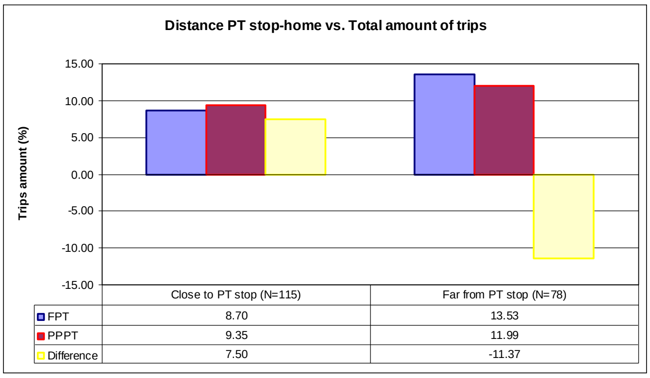


(Figure 15)

There is very little difference in the total amount of trips between the policies for people who use the car frequently. In general for this group the difference is slightly positive due to pre-paid PT **(Figure 15)**. But for non-frequent car users there is a significant difference. They tend to decrease the amount of trips that they make significantly.

People who commute by public transport decrease their total amount of trips due to the pre-paid policy **(Figure 16).** However the results also show that the people not commuting by PT increase their total number of trips.





(Figure 16) **Figure 17)**

People close to public transport stops tend to make significantly more new trips due to the pre-paid policy **(Figure 17)**. The opposite is also true; people who live far from the PT stops reduce their total amount of trips made. This may imply that the accessibility of public transport plays an important role concerning the pre-paid.

6.5.3 Opinion towards the policy

In the previous paragraph some results were explained by suggesting that people's attitudes have influence on the answers given in the survey. In this section results are presented covering the opinions of respondents about the policy.

Approximately half of the respondents were positive about the policy. Those who were negative mostly argued that the policy is unfair and inefficient as Sydney has many rural locations that are not readily or effectively serviced by public transport. The previous survey results support this as we have seen: people who live close to PT stops tend to replace more car trips by PT and take many more trips than those who live far from a public transport stop. This is evidence that attitude towards policy have an influence on the answers given. Some respondents also argued that the policy is unfair for some people who never will use the public transport and that it should depend on yearly incomes.

6.6 Statistical Analysis

In this paragraph the statistical confidence and significance is determined. First the statistical confidence is examined through an assessment of the sample group compared to the target group, confidence levels and confidence intervals. In the following part the statistical significance of the results is tested through a one sampled T-Test, carried out in SPSS 14.

6.6.1 Statistical confidence

The results obtained from the survey can be divided in two categories. The first one compares the two policies on the total replaced car trips and total amount of trips, based on the whole sample (i.e. 193 respondents). The other compares the two policies based on specific groups in the sample, for example car use frequency and car use activity.

Category 1
As this sample category comes closest to being representative of Sydney with respect to the travel mode (the car), this category is used to examine the differences between the two policies. The results are most valid to use in TRESIS. Also the larger sample size contributes to decrease the uncertainty of the results.

The sample consists of 42% commuting trips and 58% non-commuting trips. This is a good balance as the literature provides us that the subdivision between the commuting trips and non-commuting trips in Sydney's peak are approximately fifty-fifty [Hensher, 2006]. This is important as it can be the case that the pre-paid effect differs between the commuting trips and non-commuting trips. Also the fifty-fifty split between the car use frequency (frequent vs. not-frequent car users) seems likely. In the sample 60% of people lived close to a PT stop (less than 500 meters) whereas 40% lived far away. This may not be the fact in reality (the literature does not provide any information about the specific case in Sydney) and may cause biases in the results as the public transport availability plays an important role in people's decisions.

As we have seen above the sample reflects the target population relatively well, however it is important to take some uncertainty into account when making conclusions about the results provided by the survey. The sample size of 193 provides a confidence interval of 7% with a confidence level of 95%.

Category 2
With this category differences are examined between specific groups in the sample. The results are much more uncertain as the sample size varies between 80 and 100, causing a confidence interval of 11% with the same confidence level as category 1. Therefore these results are less valid for modeling in TRESIS. Also due to the uncertainty the results are rather interpreted qualitatively than quantitatively in contrast to category 1.

6.6.2 Statistical significance

The results show a very small difference between the two policies. To test weather these small difference between the policies are statistically significant One-Sample T-Test is used, and carried out in SPSS 14 (i.e. is there a statistical foundation that there is a difference between the two policies). The One-Sample T-Test compares the mean score of a sample to a known value. In this case the mean score is the mean of differences between the two policies of each respondent. The known value is in this case 0 as then there is no pre-paid effect. Two hypotheses are tested:

Hypotheses
<u>Null:</u> There is no significant difference between the sample mean and the known value.
<u>Alternate:</u> There is a significant difference between the sample mean and the known value.

There is a significant difference if the significance gained from the T-Test is less than 0.05. If it is higher than 0.05 then there is no significant difference between the two policies.

Each of the results presented in the previous chapter is tested on significance with the known value equal to zero. The results of the test show that in none of the cases the difference between the policies is significant. The best significance value was greater as 0.45 whereas value 0.05 or lower is required. Below (Figure 18) the graphical results from the T-Test carried out on the results "Replaced Car trips by PT" are presented. As can be seen the sample has a relatively large standard error and a significance level of 0.809, resulting in no significant difference. This case is described as an example, the T-Test results of the other survey results can be found in Annex 9.

Replaced car trips by PT

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Diffenrce in policies	193	.36	20.776	1.495

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Diffenrce in policies	.243	192	.809	.363	-2.59	3.31

Figure 18: One Sampled T-Test results on 'Replaced car trips by PT'

The conclusion that is drawn by this test is that there is none difference between the two policies. The hypothesis on the pre-paid effect is rejected.

6.7 Conclusion

Based on the survey results it can be concluded that there is no significant difference between the two policies. The hypothesis that pre-paid effect causes a much larger modal shift from car to public transport then it is now the case is rejected.

Opinions about the policy are divided. Approximately half of the respondents is positive about the policy. Those who were negative mostly argued that the policy is unfair and inefficient as rural locations are not readily or effectively serviced by PT. The unfairness for those who never use public transport is also mentioned often.

The results show no significant difference between the policies, but it has to be kept in mind that respondents tend to give answers in a short term perspective. When giving answers they state what they would do if that policy would start tomorrow or in two weeks. In a lot of cases people need time to adjust their behavior to policies, as we have seen in the literature. Therefore, it is possible that on long term there ís a significant difference between the two policies.

The results from the survey are not useable in TRESIS to draw conclusions on the effects of the prepaid policy considering CO_2 emissions and travel times, as the effect doesn't exist. However, it is possible that on the long term, there is a significant difference causing the pre-paid effect. Because of this the found values of the pre-paid effect will be implemented in TRESIS to examine the effects of such increasing PT modal share, regardless of the existence of the effect.

7. TRESIS – Sydney case

This chapter concentrates on the consequences that free public transport and the possible pre-paid effect on the long term has on CO_2 emissions and travel times in Sydney. To achieve this, first the effects of free public transport on CO_2 emissions and travel times are examined in TRESIS. Then, based on the survey results, we use TRESIS to estimate changes of a slightly larger PT modal share on reduction of CO_2 emissions and travel times.

7.1 Introduction

To estimate the shares of specific modes TRESIS uses the *concept of utility*. Together with several databases, as 'behavioral model estimation database' and 'vehicle database', the mode choices estimated by the utility function form the groundwork for the estimates on CO_2 emissions and travel times in Sydney region. A detailed description of TRESIS can be found in Annex 10. The utility functions are displayed below.

$$V_{Train} = -1.62898 - 0.025029 \cdot sc \cdot Time - 0.33682 \cdot sc \cdot Cost - 0.04174 \cdot sc \cdot Acces - 0.04174 \cdot sc \cdot Egress - 0.011306 \cdot sc \cdot Freq. \quad (1.3)$$

$$V_{bus} = -2.03439 - 0.025029 \cdot sc \cdot mTime - 0.33682 \cdot sc \cdot Cost - 0.022043 \cdot sc \cdot Acces - 0.022043 \cdot sc \cdot Egress - 0.011306 \cdot sc \cdot Freq. \quad (1.4)$$

Where, V is the outcome of the utility function. The coefficient without an attribute presents the *alternative-specific constant* representing the net influence of all unobserved or not explicitly included characteristics. The sc-coefficient, accompanying each of the attributes, is the stated choice for the attributes equals to +0.4. The included characteristics that determine the outcome of the utility for public transport are:
Time: this is the in-vehicle time of the public transport mode for a specific origin-destination zone
Cost: this is the fare price of the public transport mode for a specific origin-destination zone
Access: this is the accessibility of the public transport stops in a specific zone
Egress: this is the accessibility of public transport stops in a specific zone
Frequency: this is the frequency of a specific public transport mode in a specific zone (modes/hour)

The purpose of TRESIS Modeling is twofold (Figure 19). In the first place TRESIS is used to estimate how free public transport affects the modal split, and with that the travel times and CO_2 emissions in Sydney region. To achieve this two different runs are done in TRESIS. The first run decreases the travel costs for trains and busses to zero for each origin-destination zone. For the utility function it means that the attribute of cost equals zero resulting in the following utility function for trains (the same applies for the busses):

$$V_{Train} = -1.62898 - 0.025029 \cdot sc \cdot Time - 0.04174 \cdot sc \cdot Acces - 0.04174 \cdot sc \cdot Eggress - 0.011306 \cdot sc \cdot Freq. \quad (1.5)$$

In the second run, besides eliminating the cost, also the level of service is adjusted to a value that may be expected resulting from free public transport. These adjustments contain a frequency increase for trains and busses as more capacity is needed to cope with the patronage growth. Further the travel times for busses are adjusted because no ticketing means shorter loading times.

$$V_{Train} = -1.62898 - 0.025029 \cdot sc \cdot Time^{Adjust.(Bus)} - 0.04174 \cdot sc \cdot Acces - 0.04174 \cdot sc \cdot Eggress - 0.011306 \cdot sc \cdot Freq^{Adjust.} \quad (1.6)$$

In the second place TRESIS is used to estimate how the increased modal share by pre-paid affects travel times and CO_2 emissions in Sydney region. Although the effect doesn't exist on the short run, the effect is implemented in TRESIS to examine the effects of such increasing PT modal share. In this run the utility functions are adjusted by the pre-paid effect gained in the survey. This is done through calibrating the outcomes of utility function and thus the modal shares in TRESIS, to values found in the survey. The modal shares in TRESIS are varied by varying the utility function outcomes.

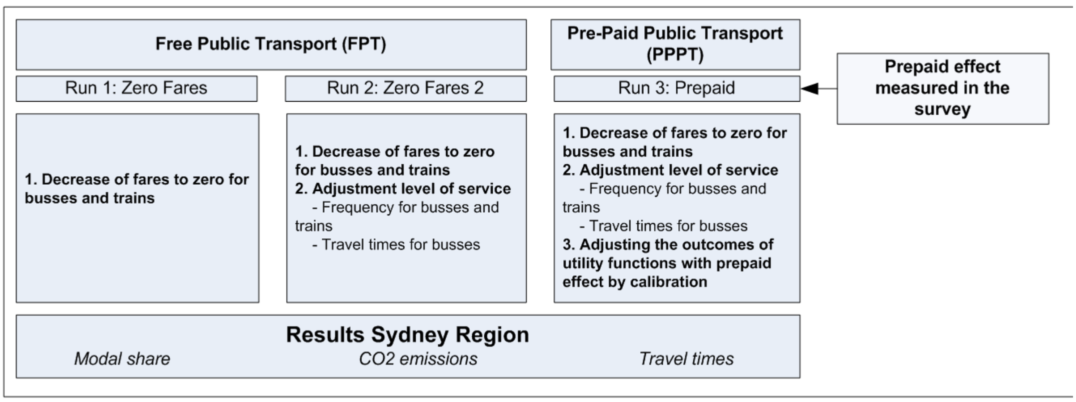


Figure 19: The TRESIS runs

7.2 Calibration

Before modeling TRESIS is calibrated with Census Data from year 2006 (the most recent year available). It can be assumed that the amount and mode choice of trips made did not change significantly in these three years. Census data contain information about the trips made in Sydney Region and indicates a modal split shown in table 3. As TRESIS does not consider ferry, bicycle and walking trips (a small proportion of total trips made), these are left out of the calibration. The same is done with shares of light rail travel and travel by bus ways.

	Car drive alone	Car ride share	Train	Bus
DIFFERENCE (%)	-0.06%	-0.02%	0.02%	-0.03%
MODAL SPLIT CENSUSDATA (%)	68.44%	7.61%	15.24%	8.63%
MODAL SPLIT 2006 (%)	68.50%	7.63%	15.22%	8.66%
Utility function outcomes	*-0.37618531*	*-2.571908708*	*-1.407227614*	*-1.770332505*

Table 3: Calibration of utility functions to census data

By running TRESIS numerous times, utility function outcomes are calibrated to recent modal shares (Table 3). As we can see in the table, the differences between the modal split of the census data and the calibrated modal split in TRESIS are negligible.

7.3 Pre-paid calibration

The free public transport runs are directly adjusted by implementing free public transport as a policy in TRESIS. However to implement a growth in public transport modal share, the growth is again calibrated. The implemented modal growth is the growth found in the survey where 1.65% more car trips are replaced by the public transport compared to the fully government subsidized FPT. The utility function outcomes are calibrated so that after the first year 1.65% of the car trips (ride alone and shared car trips) are replaced by public transport (train and bus trips). The distribution of those 1.65% across bus and train is calculated proportionally to the existing shares. In table 4 the results of the calculations, together with the new modal split after one year, are given.

	Car		PT	
Total mode share FPT	0.7613		0.2387	
Total mode share PPPT	0.7487		0.2513	
Proportions TDA/TRS vs. Ttrain/Tbus	8.9777		1.7581	
	TDA	**TRS**	**Ttrain**	**Tbus**
New Mode Shares (1.65%)	***0.6653***	***0.0834***	***0.1602***	***0.0911***

Table 4: New modal shares due to PPPT after 1 year

With this modal split the parameters in TRESIS are calibrated. Table 5 shows the results of the calibration. The differences between the target modal split and the calibrated modal split are negligible.

	Car drive alone	Car ride share	Train	Bus
DIFFERENCE (%)	0.011%	0.003%	-0.010%	-0.003%
MODAL SPLIT CENSUSDATA (%)	66.530%	8.340%	16.020%	9.110%
MODAL SPLIT 2006 (%)	66.519%	8.337%	16.030%	9.113%
Utility function outcomes	*-0.396776806*	*-2.474492566*	*-1.309935097*	*-1.682095938*

Table 5: Calibration pre-paid public transport

7.4 Assumptions

In this section the assumptions concerning the model runs are made.

7.4.1 Mondeling timeframe

The modeling timeframe for all the cases is set to 8 years, from 2009 till 2016. This choice was made because behavior tends to change in the mid- and long term as people need time to adjust their behavior to policies. This counts only for the zero fares as they can be modeled in TRESIS. It has to be stated that the long-term forecasts which are usually the most important for decision makers may not be as reliable in TRESIS as needed [Kijk in de Vegte & Sinnema, 2000.]

7.4.2 Variable adjustments

Making the public transport free implies a patronage growth affecting the level of service. The level of service-variables for public transport in Sydney that can be adjusted are: fares, in-vehicle time, access time, egress time and frequency. The variable adjustments can be distinguished between buses and trains. Assumptions about these variables for these two modes are described below.

Bus

It is assumed that free public transport does not have any effect on access and egress of bus stops. This can be assumed as it is not expected that there will be any additional bus stops and stations. However, it is assumed the frequency needs to be increased to be able to cope with the growing patronage. The needed frequency increase is estimated with the observed patronage growth from the Zero Fares-case. It is assumed that the increase in the number of trips is proportional with the needed frequency increase. Furthermore, we assume that the increase is evenly spread through the region.

Example: If due to free public transport the amount of trips increases with 50% compared with no policy, the frequency will also have to increase with 50% to be able to cope with this patronage growth. So if the frequency of buses was 4 in an hour it increases to 6 in an hour.

Increase in Bus trips	Year
49.07%	2009
48.55%	2010
48.40%	2011
47.99%	2012
47.92%	2013
47.78%	2014
47.47%	2015
47.34%	2016

Table 6: Increase in bus trips due to free public transport

According to Table 6 above, the biggest increase in bus trips that occurs is 49%. Therefore all bus frequencies in Sydney will be increased by 49%.

Besides the needed frequency increase, it is assumed that due to free public transport the in-vehicle time of buses will decrease. As it is not necessary to buy a ticket on the bus the loading times will decrease drastically and with them the in-vehicle times. How much the decrease is, will differ if the current buses are prepaid or standard. For the simplicity it is assumed that it the fleet consists of standard buses.

According to research by Adebisi (1981) the mean loading times for buses are 111 seconds. These findings might be dated because of the newer and faster ticketing systems. Therefore we estimate the loading times at 90 seconds. With no ticketing included it is expected that the mean loading times will be approximately 30 seconds. In this case the in-vehicle time will decrease with 1 minute for each stop.

To be able to translate this decreasing in-vehicle time in TRESIS the shortest bus connection is used. It is assumed that this connection which has an in vehicle time of 5.91 minutes and a length of 1.97km consists of one stop. With a decrease of in-vehicle time of one minute per stop, the in-vehicle time will decrease approximately 17% on average. This all assuming that the amount of the stops depends on the distance between the origin and destination (i.e. the relation between the distance and the amount of stops is linear).

Train

For trains the same assumptions are made as for the bus except for in-vehicle times. As at the moment ticketing takes place before getting on the train, a lack of ticketing will not lead to a reduction of loading times for trains.

Based on the increase in train trips due to free public transport (Table 7) an increase of 21% in train frequency is needed to be able to cope with the patronage growth.

Increase in Train trips	Year
20.89%	2009
20.37%	2010
20.32%	2011
20.00%	2012
19.61%	2013
19.42%	2014
20.19%	2015
18.87%	2016

Table 7: Increase in train trips due to free public transport

7.4.3 Uncertainty

Modeling brings uncertainty along as a model is not able to account for every phenomenon that occurs in reality. Below a short summary is given about the factors that may influence the results obtained from TRESIS.

Census data

As mentioned above before modeling, TRESIS is calibrated with census data from the year 2006- consisting of trips that are not available in TRESIS (i.e. ferry, walk, cycle and non-commuting trips). Although it can be assumed that the amount and mode choice of trips made did not change significantly in these three years, the fact that TRESIS only takes account of commuting trips may lead to errors. The magnitude of those errors is hard to obtain.

Long- vs. short-term effects

The uncertainty about the effects that might occur on the long term is two-fold. In the first place, TRESIS is not very reliable in forecasting long-term effects [Kijk in de Vegte & Sinnema, 2000.]

Elasticity of free public transport

The public transport utility functions in TRESIS have a linear component for the cost (i.e. as the price increases the patronage decreases proportionally, and the other way around). This might cause errors as the price elasticity's tend to be different when price decreases are high, as seen in the literature review. Also, the price sensitivity is higher when prices increase than when they decrease. For TRESIS modeling this means that the disutility of cost, when they are low, is underestimated. This can lead to outcomes of utility functions that are too low, comparing with the reality.

System simplicity

The simplicity of a system can play a great role in attracting new users. For example, under free PT people do not have to worry about buying tickets and standing in queues to pay and submit tickets before boarding. This is not taken into account in TRESIS and therefore could cause errors in the results, leading in underestimation of the public transport mode shares.

7.5 Results

In this paragraph the results relating to the model runs are shown. To simplify the interpretation of the results, it is chosen to give answers on the research questions whilst focusing on key output variables. The following output data are used:

1. Modal split characteristics and total number of annual trips for car drive alone, car ride share, train and bus. (TDA, TRS, Ttrain, Tbus)
2. The total annual carbon dioxide emissions (TCO_2)
3. Total annual end-use commuter travel time (TEUC.Time)
4. Total annual passenger vehicle kilometres (TVKM)
5. Total annual passenger vehicle kilometres: to/from work and as a part of work (TVKMTwAw)

The results show that free public transport (Free Fares 2) causes a 2.5% decrease in annual CO_2 emissions. The increase in public transport modal share of 1.65% (as found in the survey) enlarges this effect with an additional 0.5%, coming to a total decrease of almost 3%. As people are persuaded to use public transport instead of the car the total annual vehicle kilometers are decreased (2.4%). Hereby, the vehicle kilometers that are made for commuting tend to decrease more. Due to free public transport the commuter travel times are decreased by 4.7% which is supported by the fact that persuading more people to use public transport reduces vehicle kilometers travelled for private vehicles, yielding a positive effect on congestion. The average decrease of 0, 5% on the variables in Figure 20 sees little with a 1, 65% decrease in car use. Car use is thus relatively inelastic to decrease in CO_2 emissions, vehicle kilometers and travel times.

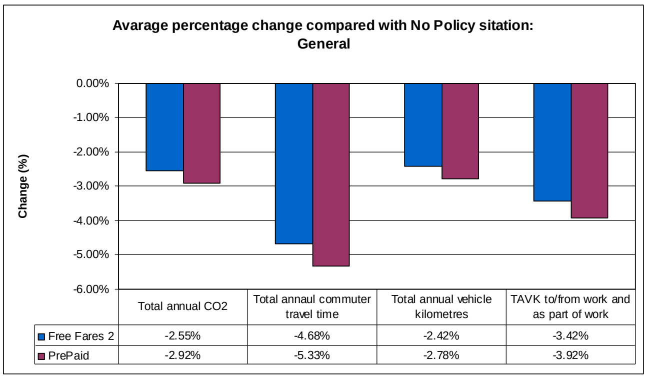


Figure 20: Average percentage change: General

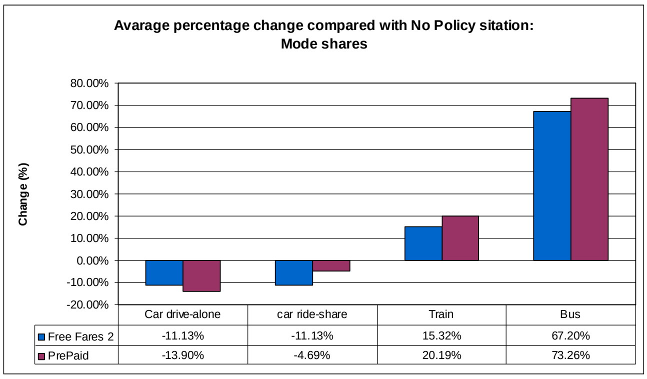


Figure 21: Average percentage change: Modal shares

Free public transport has a significant effect on the modal split. As can be seen in Figure 21 the modal share of car drive-alone and car-rideshare tend to decrease by 11% compared to the current mode split values. The effect of free public transport is most extreme with regard to bus use. Compared to the current values, bus use increases by 67% under free PT. The increase in public transport modal share of 1.65% increases this effect by another 6%. The effects on train use are less extreme but are nevertheless significant with a 15% and 20% increase for free PT and pre-paid PT, respectively. A small decrease in car use leads thus to a large increase in public transport modal shares.

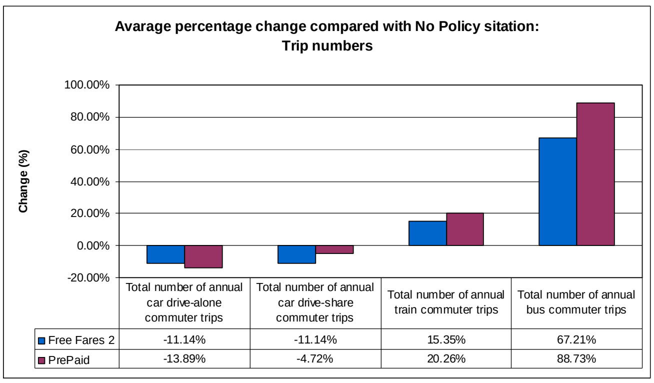


Figure 22: Average percentage change: Trip numbers

The amount of trips made by car tend to decrease under free PT as they are now made by public transport, causing an increase in trip numbers for public transport. As well as with mode shares, the increase in bus trips is much larger than the increase in the amount of train trips (Figure 2).

7.5.1 Trends

In the previous paragraph the effects of free public transport and a prepaid policy are compared with the current situation. This paragraph concentrates on absolute values and long-term trends of both policies.

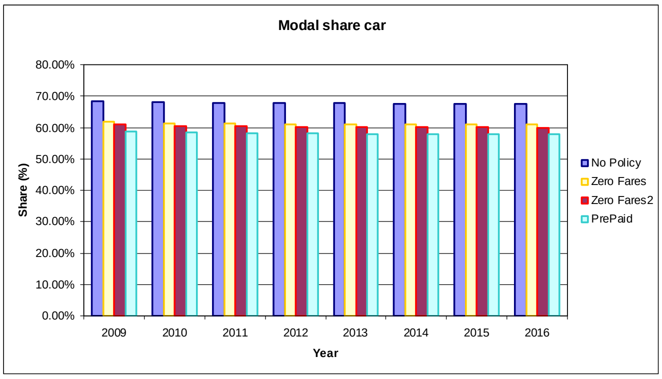


Figure 23a: Modal share car alone

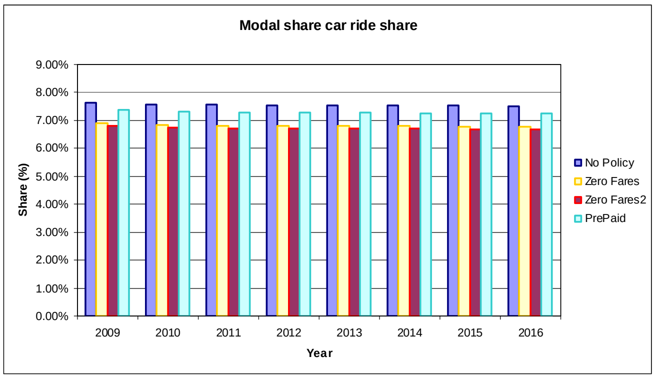


Figure 23b: Modal share car ride share

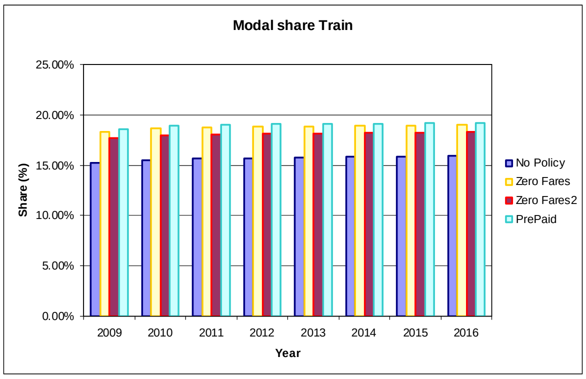


Figure 23c: Modal share Train

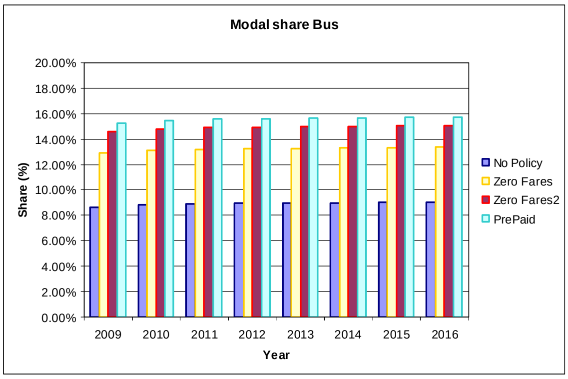


Figure 23d: Modal share Bus

The results do not show a significant difference between the short and long term. Over time there is a slight decrease in car use and an increase in public transport use. However, these differences in the short- and long-term seem to be the same for each policy (i.e. no policy shows the same trend as a free public transport policy). This means that these slightly upward and downward trends are not caused by the policy itself. The trends are expected and are forecasts rather than effects of a certain policy. This supports the previous findings that TRESIS is not reliable in forecasting effects in the long-term.

7.6 Conclusion

From the model runs we can conclude that free public transport have a significant effect on modal shares. The effects on CO_2 emissions and travel times are less powerful than on mode switch, however, there are visible. Especially on the long term these policies may have a much greater influence than the short term effects which are elaborated in this report. Also factors of simplicity of the system are not taking into account in TRESIS.

Considering the effects of a small extra switch from the car to public transport it seems that car use is relatively inelastic to decrease in CO_2 emissions, vehicle kilometers and travel times. On the other hand a small decrease in car use leads to a large increase in public transport modal shares.

8. End Conclusions

Below the end conclusions are presented with the research questions described in the chapter 'Research Plan' as the point of departure

1. Free public transport has a significant effect on modal shares. Also FPT affects the CO_2 emissions and travel times significantly however these are less powerful than on mode switch. According to literature the effects of policies influencing individual travel behavior tend to be greater on the long term, implying that this policy maybe a effective tool to influence modal shares, CO_2 emissions and travel times.
2. The measured pre-paid effect is not significant and therefore doesn't exist on the short term. Therefore prepaid public transport is not an effective measure to influence the modal split, CO_2 emissions and travel time. The effects on the long term are unknown.

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ANNEX

Annex 1: Concrete policy for Sydney

The policy described in the introduction of this report will be applied on a concrete situation, in Sydney (Australia). The supposed hypothesis will in this case concern the inhabitants and commuters in Sydney. They are annually charged with an explicit tax for public transport enabling them to travel with zero marginal cost with the main public transport modes in Sydney – train, bus and ferry. The amount of this charge will be estimated later on in this chapter together with other assumptions about the policy.

For the government of New South Wales this means that the amount of money that was first generated through fare revenue in Sydney now will be obtained by the explicit tax on the inhabitants and commuters in Sydney. The amount of the subsidy remains the same. The new situation is shown below (Figure 24).

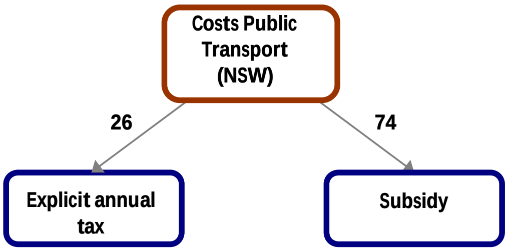


Figure 24: PT structure with explicit tax

In this chapter the policy boundaries will be established. A distinction will be made between physical and non physical boundaries. The level of public transport in Sydney is described and finally the annually tax charge for public transport will be estimated.

Public transport in Sydney

To determine in which part of the area the policy is valid, the public transport networks are observed. Below a short summary is given about the three most used public transport modes in Sydney, namely rail, bus and ferry [Wikipedia].

Rail

Sydney has a branched suburban train service with its 11 railway lines. In the metropolitan areas the train service has characteristics of a metro and is for a large part underground. Outside this area the trains run mostly above the ground. In the peak hours the most lines are very frequent with more than five trains per hour. The train network is also integrated with neighboring regions as Blue Mountains, Newcastle, Illawarra, Southern Highlands, Central Coast and leave from Sydney central railway station. Sydney's train network map is attached in annex 5.
As we can see on the map, the rail network is very dens in the metropolitan area and less dense in the suburbs and neighboring regions. Although almost every suburb of Sydney is reached by the train network, for the most outer suburbs and neighboring areas a second mode is needed to reach the destination.

Bus

Sydney's bus service is tightly integrated with train and ferry service. It accounts for ca. the half of the public transport journeys. As the train network the bus service considers the regions surrounding Sydney as a part of the metropolitan network. However the bus service is much denser in these suburbs and neighboring areas compared to the train. In the map (Annex 6) the regions served by the bus service are showed.

Ferries

The ferries are active on Sydney Harbour and are used in equal measure by commuter and leisure users and on the Parrametta River, mainly used by tourists. With its 14 million passengers per year it is relatively small portion of the total trips made with public transport.

As we can see Sydney in the most of the areas has a wide range of possibilities to choose when travelling with public transport. Although the outer suburbs and neighboring regions are less accessible than the urban area the networks are widespread in such a way that the commuters have enough chances to connect to these networks with or without a second mode.

[Public transport in Sydney, 2009]
[Railways in Sydney, 2009]

Policy boundaries

In this paragraph the policy boundaries for the specific situation in Sydney will be described. The way in which the policy is applied depends on these boundaries. Two sorts of boundaries are distinguished: physical and non-physical boundaries.

Physical boundaries

As the considered policy depends on the fact which area can be labelled as Sydney the physical boundaries of Sydney's district play an important role. In this paragraph these boundaries are described.

Sydney's urban area covers 1 687 km^2 however, the unofficial metropolitan area covers 12 145 km^2 which includes the Central Coast, the Blue Mountains and other un-urbanized land. This is Sydney's statistical division and official Sydney's border (Annex 3). This area has a population of nearly 4.4 million inhabitants and consists of fourteen regions. These are: Sydney CBD Eastern Suburbs, Hills District, Inner West, Canterbury-Bankstown, Northern Beaches, Northern Suburbs, North Shore, St George, Southern Sydney, South-eastern Sydney, South-western Sydney, Sutherland Shire and Western Sydney. In TRESIS all of these regions are modeled even though the names may differ in some cases (Annex 4). However the regions correspond with the Sydney's official regions and borders [Wikipedia].

The people who are living in the main urban area will benefit the most of the policy as there the public transport service is better than in the neighboring regions. However the policy also aims at the commuters to Sydney that originally travel by car, which for the most cases live in these outer suburbs and neighboring regions. For this reason it is important to take the whole Sydney region (Annex 3) into account when applying this policy.

Non physical boundaries

Above we have seen in what area the policy is applied. Besides this there are a few non physical assumptions that have to be made. These include the exactly definition of people on which the policy is valid.

Assumptions

1. As it is not likely that very young people will use the public transport we will only take into account people above 14 (as then they finish their secondary school and are probably going to travel more). As we want to persuade the discretionary car riders the policy shouldn't take into account the dependent drivers who already are using the public transport. For this reason the policy won't apply for people older than 65. The revenue gained by the explicit tax and the height of the tax depends on this assumption. According to Sydney statistical division (2006) 2.8 million of the total 4.1 million inhabitants in Sydney are eligible for the policy.

2. The parents will have to pay the amount for each child above 14 years of age. So the price paid will differ with the household, but per person it will remain the same.
3. For the simplicity of the survey questions we assume that the level of service after introducing the policy will be the same as it is now.
4. The increase of running cost due to policy will directly be levied through the policy, so the subsidy will remain the same. For this reason the tax may be higher than it would be the case with current service cost. This increase will be taken into account when estimating the tax. The possible new vehicles that may be necessary however are not accounted in this policy as they are onetime purchase cost.

Annual tax estimation

The magnitude of the tax amount that the residents and commuters to Sydney urban pay will have effect on their decisions in which mode to choose. This magnitude depends on the amount of people that will be taxed and the fare revenues that are gained at the moment, as the fare revenues are going to be covered by the explicit tax. As there is no data on the fare revenues specifically originating from Sydney an assumption will be made using the data from New South Wales (NWS).

Facts, New South Wales (NSW) [The Daily Telegraph, April 20, 2009]

- NSW has Public transport running cost of $3.8 billion per year
- 26% of these costs are from fare revenues – train/bus/ferry's (2007/2008) = $ 998 million
- 74% of these costs are paid by subsidy = $2.8 billion
- Population: 6.9 million

The proportion of the public transport running cost for Sydney is estimated by assuming that the running cost for a certain area are proportional to the number of inhabitants in that area. So the running costs for Sydney are as high as Sydney's population divided by the population of New South Wales. Further it is assumed that the percentages of fare revenues and the subsidy in Sydney are comparable to New South Wales (26% for fare revenues; 74% subsidy).

	Population	Running costs p/y	Fare revenues p/y	Subsidy p/y
NSW	6.9 million	3.8 billion	1 billion	2.8 billion
Sydney	4.1 million	*2.3 billion*	*600 million*	*1.7 billion*

Table 7: Estimation fare revenues in Sydney

In table 7 is estimated that Sydney has running costs of 2.3 billion per year of which 1.7 billion is subsidized and 600 million is gained from fare revenues.

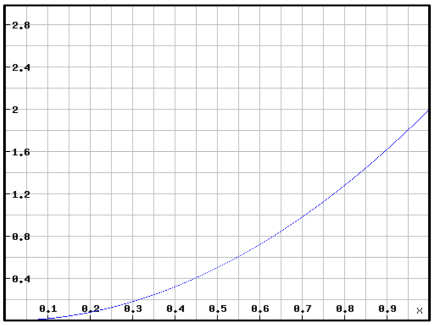
As defined in the non physical boundaries, for the simplicity of the survey questions we assume that with the policy the service level will remain the same as it is now. However, this assumption is invalid for the running cost as higher patronage needs increased capacity and frequency to maintain the same service level. This means that the fare revenues have to be much higher and therefore adjustments have to be made for the annual tax. In the next paragraph assumptions are made on these and other influences on the annual tax.

Influences on the annual tax

To maintain the same service level the cost for public transport will increase as the patronage increases. The improvements that are needed to maintain the same service level may be capacity increase and in some cases frequency increase. On the other hand the running cost will decrease due to less costs of staffing like ticket machine operators. As the exact effects on running costs of these influences are hard to obtain and there is hardly literature on this subject a simple assumption is made.

It can be assumed that the running cost double when the patronage doubles as for doubling of patronage twice as much effort is necessary. The costs of possible new vehicles that may be necessary to cope with the patronage growth are excluded. However this relation isn't likely to be a linear one. In the beginning when the patronage growth is very low, say 5%, almost no extra running cost will have to be made as the system only needs expansion when the capacity is exceeded. Therefore the relation is more likely to be graduate, which can be expressed with a quadratic function.
The described assumption includes that the relation between the running cost and the patronage increase is $1/10x^2$ resulting in a graduate relation which doubles the cost if the patronage doubles. However to leave some margin as this assumption is uncertain and other running cost may apply to the patronage increase the function is assumed to be $1/5x^2$ (Figure 25).

Running cost (% x 100)



Patronage increase (% x 100)

Figure 25: Increase in running cost due to patronage increase $1/5x^2$

According to this assumption a 20% increase in patronage means a 10% increase in running cost, likewise a 70% in patronage growth means a 100% increase in running cost.

In the case of the considered policy the increase in the running cost and so in the annually tax depends on the patronage increase caused by the policy. To estimate the patronage increase we turn to the results of the research by Studenmund & Connor (1981) who examined the effects of a free public transport policy in the off-peak. According to this research the patronage increases by almost 50%. As there is no literature about the patronage increase due to a free fare policy throughout the day we are forced to use this assumption in order to calculate the annually tax.

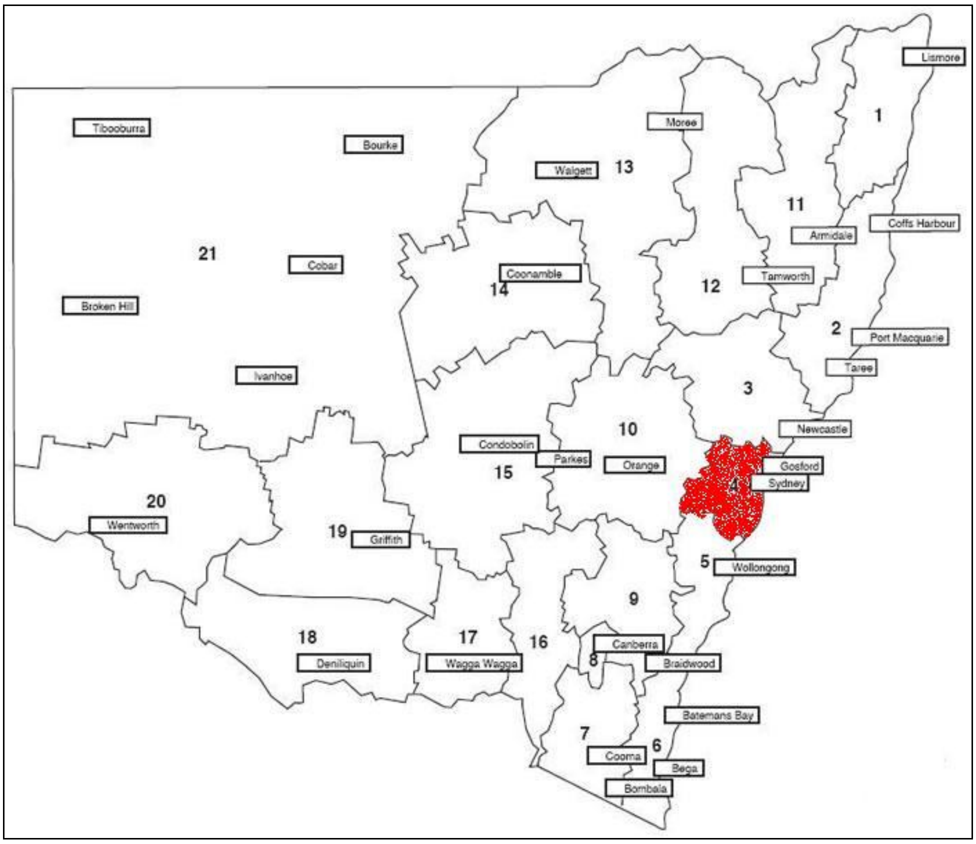
Annual tax

Now that the assumptions are made and reasoned we are able to calculate the annually tax on people between 14 and 65 years of age:

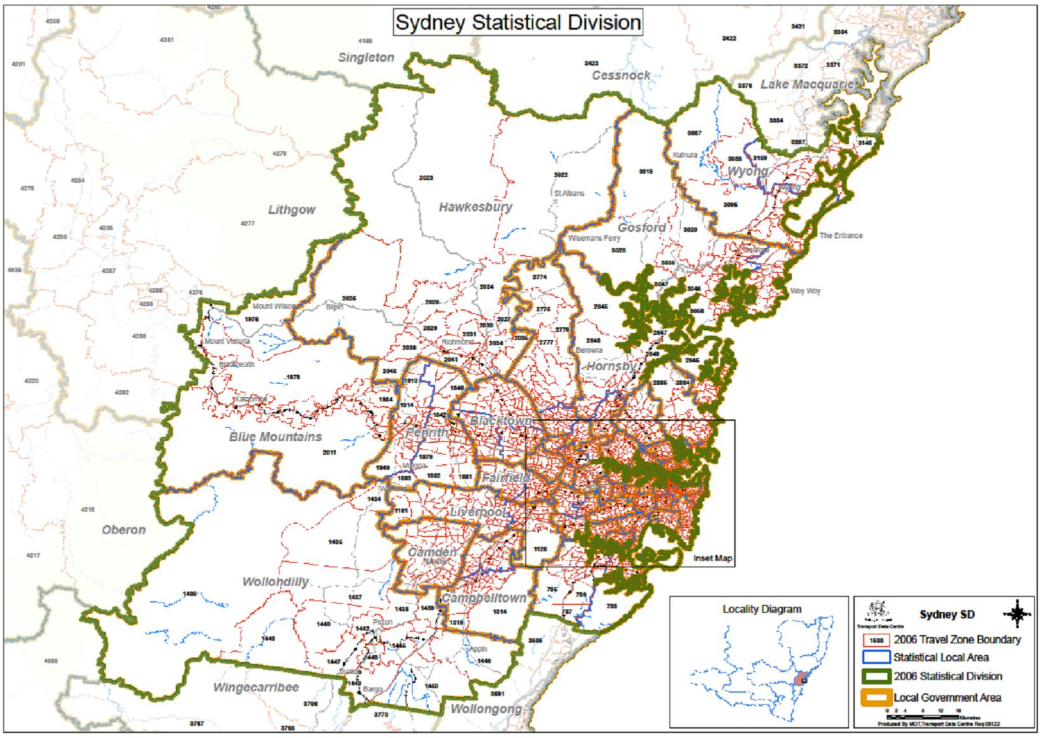
	Inhabitants	Running cost p/y	Adjusted run. cost (+50%)	Fare revenues	Annual tax
Sydney	$2.8 million	$2.3 billion	$3.5 billion	$3.5 -$1.7. = $1.8 billion	$650

Table 8: Estimation annual tax

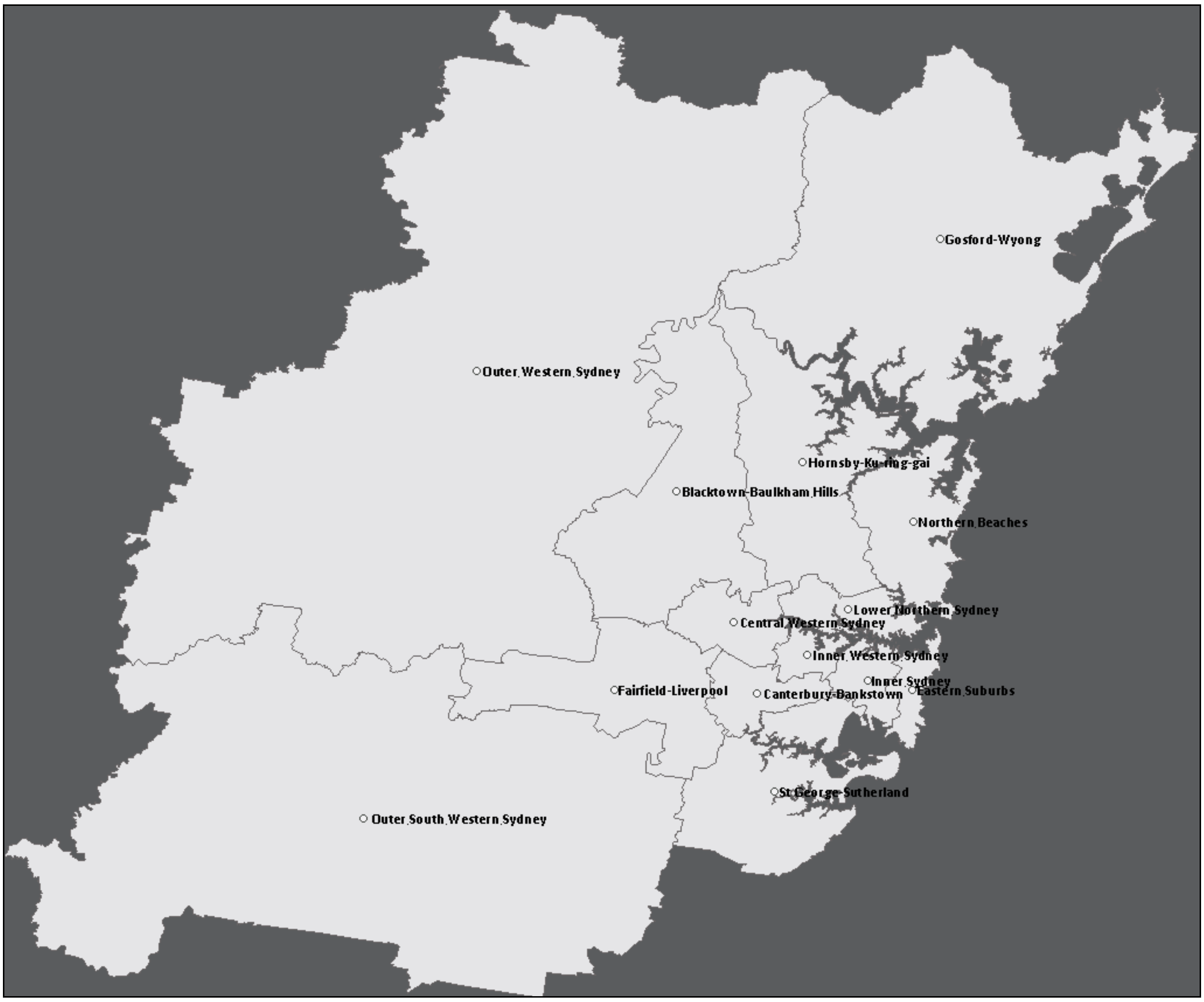
Annex 2: Location Sydney district in New South Wales (NSW)



Annex 3: Official Sydney boundaries

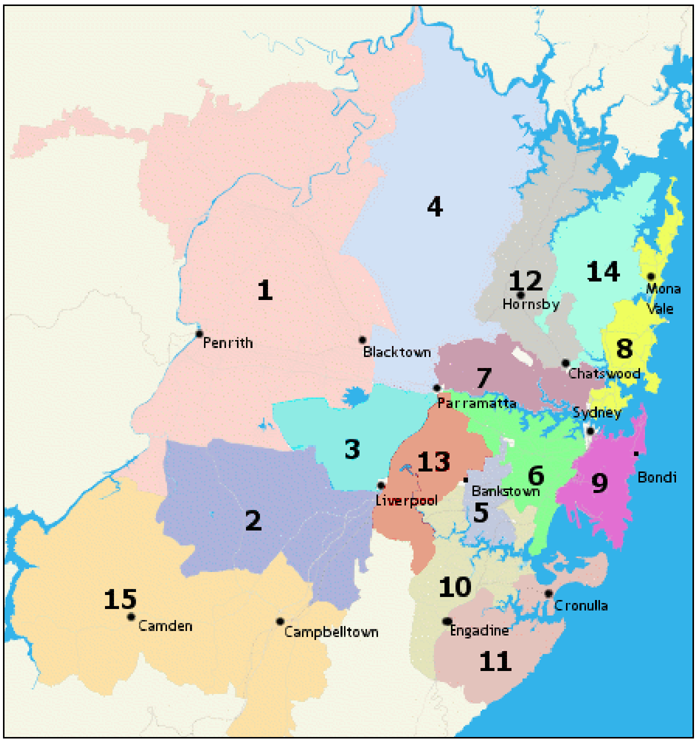


Annex 4: Map of Sydney boundaries by TRESIS

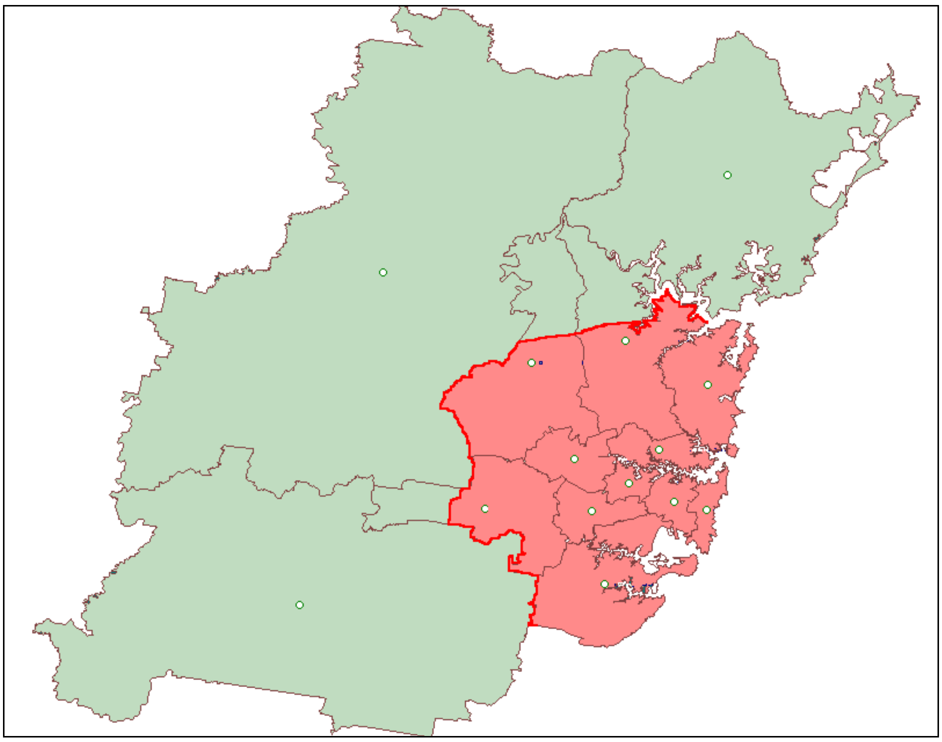


Annex 5: Sydney's rail network map

Annex 6: Regions fully served by the bus services



Annex 7: Sydney urbanized area (red), Sydney unurbanized area (green)



Annex 8: Survey questions

Pricing of public transport: the key to green cities?

People who work or live in an urban area are confronted daily with traffic congestion and polluted air. Spare time is lost and our health is being influenced by daily traffic. Despite the consequences that excessive car use causes, persuading people to use more efficient and environmentally friendly modes is a difficult task.

The aim of this survey is to investigate how people react to policies intended to persuade car drivers to use public transport more frequently. During the questionnaire imagine that the described policies have been introduced. It is important to be aware that your responses to each policy are significant for this research – your opinion matters.

The collected data will only be used for this research and will not be passed on to third parties. This research is being carried out within the framework of an undergraduate assignment in cooperation between Institute of Transport and Logistics Studies at the University of Sydney and Twente University (The Netherlands).

The survey consists of 12 multiple choice questions and can be completed within five minutes. Once you submit your responses for a page you cannot go back and change them, so please select your answers carefully. When you are done, please press the 'Finish' button.

Privacy statement
This questionnaire is anonymous. No one will be able to identify the source of any responses.

Thank you in advance,

Srdjan Timotijevic
Institute of Transport and Logistics Studies
Twente University (The Netherlands)

General questions

1. Are you between 18 and 65 years old?

   i. If you are not between 18 and 65 years old, the following questions are not applicable and you can quit the survey. Thank you for your time.

   - Yes
   - No

2. How frequently do you use a car?

   i. If you never use a car, the following questions are not applicable and you can quit the survey. Thank you for your time.

   - More than once a day
   - Once a day
   - Once in a few days
   - Once a week
   - Once a month
   - Never

3. For which 2 activities do you use a car the most?
   - Travelling between home and main work place (i.e., commuting)
   - During work
   - To get to/from education
   - To get to/from a recreation activity
   - To get to/from the shops
   - Other:

4. How often do you use public transport?
   - More than once a day
   - Once a day
   - Once in a few days
   - Once a week
   - Once a month
   - Never

5. For which 2 activities do you use public transport the most?
   - Travelling between home and main work place (i.e., commuting)
   - During work
   - To get to/from education
   - To get to/from a recreation activity
   - To get to/from the shops
   - Other:

The next section focuses on two pricing policies for public transport. In both cases please imagine that the described policies have been introduced. It is important to be aware that your responses to each policy are significant for this research – your opinion matters.

The following questions consider the Sydney area which is defined on the map below and includes next to the central area: Wollondilly, Blue Mountains, Hawkesbury, Gosford, Wyong, Hornsby, Blacktown, Penrith, Fairfield, Liverpool, Camden and Campbelltown.

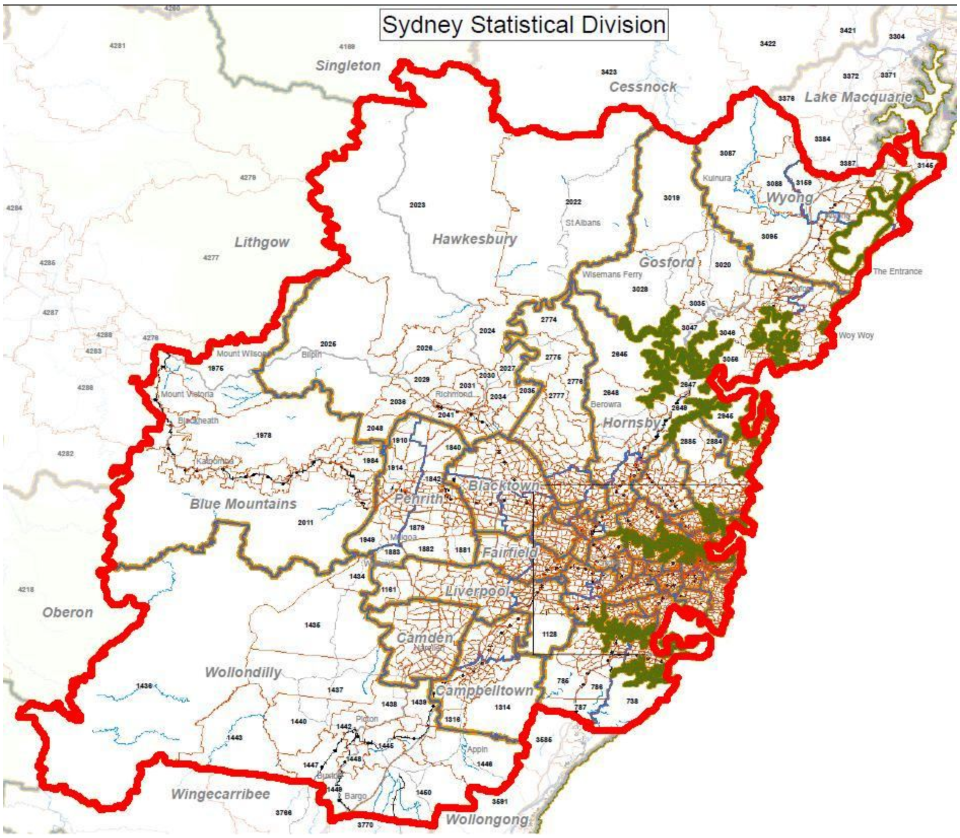


Figure 1: The Sydney area is surrounded by the red line

6. Do you live and/or work in the described area?
   - Yes
   - No

i. If you say no, the following questions are not applicable and you can quit the survey. Thank you for your time

7. What is the approximate distance from your home to the closest public transport stop (bus, train or ferry)?
   - Less than 500 meters
   - Between 500 meters and 1 kilometre
   - Between 1 and 2 kilometres
   - More than 2 kilometres

Policy 1

Suppose that, to encourage people's usage, public transport (including buses, trains and ferries) in the area defined above is made FREE by the government of New South Wales for all inhabitants of this area.

8. If the service level (frequency, crowdedness, comfort) remained the same, what proportion of the trips that you made by car would you replace with trips by public transport?

None of the trips O O O O O O O O O O O All trips

(i): 1 star = none of the trips; all stars = All trips

(Six stars would be the half of the trips)

9. How many trips in total would you be likely to make under this policy compared to now? (Please select the closest answer)
    - 25% less then now
    - 15% less than now
    - 5% less than now
    - The same as now
    - 5% more than now
    - 15% more than now
    - 25% more than now
    - 50% more than now

Policy 2

Now let's consider a different policy that involves the payment of an annual fee for access to unlimited free trips by public transport. Imagine that every inhabitant of the Sydney area between 18 and 65 years old, including you, is obligated to pay every 30th of January an amount of $650 for public transport in the Sydney area. This payment would give you unlimited travel with buses, trains and ferries within the Sydney area for the next year.

10. If the service level (frequency, crowdedness, comfort) remained the same, what proportion of the trips that you made by car would you replace with trips by public transport?

None of the trips ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ All trips
(i): 1 star = none of the trips; all stars = all trips
(Six stars would be the half of the trips)

11. How many trips in total would you be likely to make under this policy compared to now? (Please select the closest answer)
    - 25% less then now
    - 15% less than now
    - 5% less than now
    - The same as now
    - 5% more than now
    - 15% more than now
    - 25% more than now
    - 50% more than now

12. What is your opinion about a policy where everybody is obligated to pay an amount of money annually for public transport with the goal of increasing its usage and improving the environment and travel times in Sydney area?

Thank you for your time!

Please feel free to forward the e-mail containing the survey link onto others who live and/or work in Sydney area.

With kind regards,

Srdjan Timotijevic
Institute of Transport and Logistics Studies
Twente University (The Netherlands)

Annex 9: Survey results & significance

Replaced car trips by PT

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Diffenrce in policies	193	.36	20.776	1.495

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Diffenrce in policies	.243	192	.809	.363	-2.59	3.31

Amount of trips in total

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Difference	193	-.23	17.465	1.257

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Difference	-.185	192	.853	-.233	-2.71	2.25

Car use frequency vs. replacing trips by PT (Frequent)

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Difference	101	.69	23.378	2.326

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Difference	.298	100	.766	.693	-3.92	5.31

Car use frequency vs. replacing trips by PT (Not Frequent)

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	92	.0000	17.60370	1.83531

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
VAR00001	.000	91	1.000	.00000	-3.6456	3.6456

Car use Frequency vs. Total trips (Frequent)

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	101	.0495	19.55115	1.94541

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
VAR00001	.025	100	.980	.04950	-3.8101	3.9091

Car use Frequency vs. Total trips (Frequent)

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00002	92	-.5435	14.94415	1.55804

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
VAR00002	-.349	91	.728	-.54348	-3.6383	2.5514

Car commuting vs. Replace (Commuting)

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	81	.0000	22.41651	2.49072

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
VAR00001	.000	80	1.000	.00000	-4.9567	4.9567

Car commuting vs. Replace (Not Commuting)

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00002	112	.6250	19.60333	1.85234

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
VAR00002	.337	111	.736	.62500	-3.0455	4.2955

Distance PT stop-home vs. Replace (Close)

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	115	1.3043	19.12662	1.78357

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
VAR00001	.731	114	.466	1.30435	-2.2289	4.8376

Distance PT stop-home vs. Replace (Far)

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00002	78	-1.0256	23.05216	2.61014

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
VAR00002	-.393	77	.695	-1.02564	-6.2231	4.1718

Distance PT stop-home vs. Amount (Close)

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00003	115	.6522	16.72169	1.55931

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
VAR00003	.418	114	.677	.65217	-2.4368	3.7411

Distance PT stop-home vs. Amount (Far)

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00004	78	-1.5385	18.53932	2.09916

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
VAR00004	-.733	77	.466	-1.53846	-5.7184	2.6415

PT commuting vs. Total Trips (Commuting)

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00001	133	-.4887	17.65478	1.53086

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
VAR00001	-.319	132	.750	-.48872	-3.5169	2.5395

PT commuting vs. Total Trips (Not Commuting)

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
VAR00002	60	.3333	17.16981	2.21661

One-Sample Test

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
VAR00002	.150	59	.881	.33333	-4.1021	4.7688

Annex 10: TRESIS model description

Model description

TRESIS is a policy advisory tool that enables policymakers to evaluate impacts of transport and non-transport policy instruments on urban travel behavior and the environment [Hensher, Bain & Stanley, 2008]. The simulator was developed by ITLS at the University of Sydney and attempts to represent the behavior of commuter travelers in Sydney. So far the model has been applied to five other different cities in Australia: Canberra, Melbourne, Brisbane, Adelaide and Perth.

TRESIS is a discrete choice model that observes choices made by individual travelers based on individual and household data. In this way TRESIS can be seen as a model at the disaggregate level. Its forecasts, on the other hand, are aggregate, to be able to represent the behavior of Sydney's population [Sinnema & Kijk in de Vegte, 2000]. As inputs for its simulations TRESIS maintains a data collection existing of:

Generic land use and transport database

This database contains of journey to work data, household sample files and Australian census data from 1996. For this research TRESIS is calibrated with census data from 2006.

Behavioral model estimation database

The database contains information about household surveys that consists of stated and revealed preference data. From this database choices about travel modes and departure times for commuting trips are obtained.

Transport system database

This database has information about road, bus and rail networks. These include network geometry, travel times, capacities and travel costs. For road networks it contains information about traffic control devices at intersections.

Land use database

Information about real estate is defined in this database. Also, various area boundaries used by different authorities are converted into discrete geographic zones that form the basis for outputs in TRESIS.

Vehicle database

This database contains information about vehicle use. Besides general information such as price estimates, the database contains information about light vehicles registered in the Sydney area and alternative-fuel vehicles [Sinnema & Kijk in de Vegte, 2000].

It has to be stated that TRESIS can only estimate impacts on commuter travel. It does not take into account pedestrians, cyclists, freight transportation and other non-commuting transport activities. This has to be taken into account as the reality shows a fifty-fifty split between commuter and non-commuter activities [Hensher, 2006]. Also, TRESIS is not built for modeling multiple modes at once. According to TRESIS, people are using the car OR the bus OR the train. Because this is not always the case -- especially in trips made by public transport -- the trips combined by more modes are defined as single trips during the calibration. TRESIS distinguishes the following mode types:

Share car drive alone	Share bus travel
Share car ride share	Share light rail travel
Share train travel	Share bus way

Table 9: Mode types in TRESIS

Within TRESIS it is possible to introduce several policies and predict their effects until the year 2017.

Annex 11: TRESIS results

NO POLICY 1995-2002

TCO2(kg)	TEUC.Time(min)	TVKM(km)	TVKMTwAw(km)	TDA(prop)	TRS(prop)	Ttrain(prop)	Tbus(prop)	TDA(num)	TRS(num)	TTrain(num)	TBus(num)	Year
6.68E+09	4.35E+10	2.20E+10	9.68E+09	0.68497	0.07630	0.15217	0.08656	4.24E+08	2.25E+07	9.43E+07	5.36E+07	2009
6.72E+09	4.35E+10	2.22E+10	9.75E+09	0.68071	0.07582	0.15523	0.08824	4.26E+08	2.26E+07	9.72E+07	5.52E+07	2010
6.74E+09	4.39E+10	2.24E+10	9.86E+09	0.67902	0.07563	0.15642	0.08893	4.29E+08	2.27E+07	9.89E+07	5.62E+07	2011
6.78E+09	4.45E+10	2.27E+10	9.96E+09	0.67802	0.07552	0.15712	0.08934	4.33E+08	2.29E+07	1.00E+08	5.71E+07	2012
6.78E+09	4.50E+10	2.28E+10	1.00E+10	0.67723	0.07543	0.15767	0.08966	4.36E+08	2.31E+07	1.02E+08	5.78E+07	2013
6.83E+09	4.56E+10	2.32E+10	1.02E+10	0.67649	0.07535	0.15820	0.08996	4.40E+08	2.34E+07	1.03E+08	5.86E+07	2014
6.87E+09	4.61E+10	2.34E+10	1.03E+10	0.67575	0.07527	0.15873	0.09026	4.44E+08	2.36E+07	1.04E+08	5.94E+07	2015
6.85E+09	4.67E+10	2.36E+10	1.04E+10	0.67503	0.07519	0.15924	0.09054	4.48E+08	2.38E+07	1.06E+08	6.02E+07	2016

ZERO FARES 1995-2002

TCO2(kg)	TEUC.Time(min)	TVKM(km)	TVKMTwAw(km)	TDA(prop)	TRS(prop)	Ttrain(prop)	Tbus(prop)	TDA(num)	TRS(num)	TTrain(num)	TBus(num)	Year
6.53E+09	4.25E+10	2.15E+10	9.38E+09	0.61883	0.06893	0.18331	0.12893	3.83E+08	2.03E+07	1.14E+08	7.99E+07	2009
6.57E+09	4.26E+10	2.17E+10	9.45E+09	0.61403	0.06840	0.18652	0.13105	3.84E+08	2.04E+07	1.17E+08	8.20E+07	2010
6.59E+09	4.30E+10	2.19E+10	9.56E+09	0.61224	0.06820	0.18770	0.13186	3.87E+08	2.05E+07	1.19E+08	8.34E+07	2011
6.63E+09	4.35E+10	2.22E+10	9.66E+09	0.61126	0.06809	0.18834	0.13231	3.90E+08	2.07E+07	1.20E+08	8.45E+07	2012
6.63E+09	4.40E+10	2.23E+10	9.72E+09	0.61057	0.06801	0.18880	0.13263	3.93E+08	2.09E+07	1.22E+08	8.55E+07	2013
6.65E+09	4.45E+10	2.26E+10	9.86E+09	0.60990	0.06794	0.18923	0.13293	3.97E+08	2.11E+07	1.23E+08	8.66E+07	2014
6.73E+09	4.51E+10	2.30E+10	1.00E+10	0.60927	0.06787	0.18965	0.13322	4.00E+08	2.12E+07	1.25E+08	8.76E+07	2015
6.70E+09	4.56E+10	2.31E+10	1.01E+10	0.60864	0.06780	0.19006	0.13351	4.04E+08	2.14E+07	1.26E+08	8.87E+07	2016

ZERO FARES 2 1995-2002

TCO2(kg)	TEUC.Time(min)	TVKM(km)	TVKMTwAw(km)	TDA(prop)	TRS(prop)	Ttrain(prop)	Tbus(prop)	TDA(num)	TRS(num)	TTrain(num)	TBus(num)	Year
6.51E+09	4.15E+10	2.15E+10	9.35E+09	0.60981	0.06793	0.17658	0.14568	3.78E+08	2.00E+07	1.09E+08	9.03E+07	2009
6.55E+09	4.16E+10	2.16E+10	9.42E+09	0.60495	0.06739	0.17959	0.14807	3.78E+08	2.01E+07	1.12E+08	9.27E+07	2010
6.57E+09	4.20E+10	2.19E+10	9.52E+09	0.60314	0.06719	0.18070	0.14897	3.81E+08	2.02E+07	1.14E+08	9.42E+07	2011
6.61E+09	4.24E+10	2.21E+10	9.62E+09	0.60228	0.06709	0.18123	0.14940	3.84E+08	2.04E+07	1.16E+08	9.54E+07	2012
6.61E+09	4.29E+10	2.23E+10	9.68E+09	0.60162	0.06702	0.18164	0.14973	3.88E+08	2.06E+07	1.17E+08	9.66E+07	2013
6.63E+09	4.34E+10	2.26E+10	9.82E+09	0.60100	0.06695	0.18202	0.15004	3.91E+08	2.07E+07	1.19E+08	9.77E+07	2014
6.71E+09	4.39E+10	2.29E+10	9.97E+09	0.60037	0.06688	0.18240	0.15036	3.95E+08	2.09E+07	1.20E+08	9.89E+07	2015
6.68E+09	4.44E+10	2.30E+10	1.00E+10	0.59979	0.06681	0.18275	0.15065	3.98E+08	2.11E+07	1.21E+08	1.00E+08	2016

PRE-PAID PT 1995-2002

TCO2(kg)	TEUC.Time(min)	TVKM(km)	TVKMTwAw(km)	TDA(prop)	TRS(prop)	Ttrain(prop)	Tbus(prop)	TDA(num)	TRS(num)	TTrain(num)	TBus(num)	Year
6.48E+09	4.11E+10	2.14E+10	9.29E+09	0.58802	0.07371	0.18591	0.15236	3.64E+08	2.17E+07	1.15E+08	9.44E+07	2009
6.52E+09	4.12E+10	2.16E+10	9.36E+09	0.58322	0.07310	0.18893	0.15474	3.65E+08	2.18E+07	1.18E+08	9.69E+07	2010
6.54E+09	4.16E+10	2.18E+10	9.46E+09	0.58145	0.07288	0.19004	0.15563	3.67E+08	2.19E+07	1.20E+08	9.84E+07	2011
6.58E+09	4.21E+10	2.20E+10	9.56E+09	0.58051	0.07276	0.19062	0.15610	3.70E+08	2.21E+07	1.22E+08	9.97E+07	2012
6.58E+09	4.26E+10	2.22E+10	9.62E+09	0.57991	0.07269	0.19099	0.15640	3.74E+08	2.23E+07	1.23E+08	1.01E+08	2013
6.60E+09	4.31E+10	2.25E+10	9.76E+09	0.57933	0.07262	0.19136	0.15670	3.77E+08	2.25E+07	1.25E+08	1.02E+08	2014
6.68E+09	4.36E+10	2.28E+10	9.91E+09	0.57874	0.07254	0.19172	0.15700	3.80E+08	2.27E+07	1.26E+08	1.03E+08	2015
6.65E+09	4.41E+10	2.29E+10	9.97E+09	0.57828	0.07248	0.19201	0.15723	3.84E+08	2.29E+07	1.28E+08	1.04E+08	2016

Percentage change No Policy vs. Zero Fares 2

TCO2(kg)	TEUC.Time(min)	TVKM(km)	TVKMTwAw(km)	TDA(prop)	TRS(prop)	Ttrain(prop)	Tbus(prop)	TDA(num)	TRS(num)	TTrain(num)	TBus(num)	Year
-2.55%	-4.67%	-2.41%	-3.45%	-10.97%	-10.97%	16.04%	68.31%	-10.95%	-10.99%	16.05%	68.45%	2009
-2.51%	-4.47%	-2.49%	-3.42%	-11.13%	-11.12%	15.69%	67.81%	-11.20%	-11.21%	15.65%	67.91%	2010
-2.56%	-4.43%	-2.32%	-3.47%	-11.17%	-11.17%	15.52%	67.51%	-11.20%	-10.99%	15.51%	67.59%	2011
-2.49%	-4.74%	-2.60%	-3.44%	-11.17%	-11.17%	15.35%	67.23%	-11.27%	-11.01%	15.72%	67.07%	2012
-2.53%	-4.69%	-2.36%	-3.15%	-11.17%	-11.16%	15.20%	67.00%	-11.10%	-10.99%	14.84%	67.07%	2013
-2.87%	-4.83%	-2.72%	-3.71%	-11.16%	-11.15%	15.05%	66.79%	-11.12%	-11.35%	15.11%	66.78%	2014
-2.38%	-4.74%	-2.08%	-3.19%	-11.15%	-11.15%	14.91%	66.59%	-11.13%	-11.31%	15.38%	66.53%	2015
-2.48%	-4.85%	-2.36%	-3.55%	-11.15%	-11.14%	14.77%	66.38%	-11.13%	-11.27%	14.56%	66.28%	2016
-2.55%	-4.68%	-2.42%	-3.42%	-11.13%	-11.13%	15.32%	67.20%	-11.14%	-11.14%	15.35%	67.21%	Average

Percentage change No Policy vs. Pre-Paid PT

TCO2(kg)	TEUC.Time(min)	TVKM(km)	TVKMTwAw(km)	TDA(prop)	TRS(prop)	Ttrain(prop)	Tbus(prop)	TDA(num)	TRS(num)	TTrain(num)	TBus(num)	Year
-2.99%	-5.42%	-2.84%	-4.05%	-14.15%	-3.40%	22.17%	76.03%	-14.14%	-3.42%	22.18%	76.17%	2009
-2.95%	-5.18%	-2.91%	-4.02%	-14.32%	-3.58%	21.71%	75.37%	-14.39%	-3.68%	21.67%	75.47%	2010
-2.99%	-5.13%	-2.74%	-4.06%	-14.37%	-3.64%	21.50%	75.00%	-14.40%	-3.44%	21.48%	75.07%	2011
-2.93%	-5.36%	-3.03%	-4.04%	-14.38%	-3.65%	21.33%	74.73%	-14.48%	-3.48%	21.72%	74.57%	2012
-2.97%	-5.36%	-2.78%	-3.75%	-14.37%	-3.64%	21.13%	74.44%	-14.31%	-3.46%	20.76%	74.51%	2013
-3.30%	-5.50%	-3.14%	-4.31%	-14.36%	-3.63%	20.95%	74.19%	-14.32%	-3.84%	21.01%	74.18%	2014
-2.81%	-5.42%	-2.50%	-3.79%	-14.36%	-3.62%	20.79%	73.95%	-14.33%	-3.80%	21.28%	73.88%	2015
-2.91%	-5.61%	-2.78%	-4.14%	-14.33%	-3.60%	20.58%	73.64%	-14.32%	-3.73%	20.36%	73.54%	2016
-2.98%	-5.37%	-2.84%	-4.02%	-14.33%	-3.59%	21.27%	74.67%	-14.34%	-3.61%	21.31%	74.67%	Average