

# Congestion pricing in urban areas - theory and case studies

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Urban transport, congestion pricing, peak hour travel, demand-side measures, case studies

*Abstract:*

This report intends to assess the demand for urban transport and how it can be managed by using congestion pricing and other measures in order to reduce congestion. Four cities are assessed: London, Singapore and Stockholm with congestion pricing schemes and Milan with a scheme primarily designed to reduce pollution. The areas assessed are: the initial conditions in the city, scheme design, traffic impact, how possible concerns have been addressed and the implementation process of the schemes. The key findings from the case studies will be used to contribute to the discussion regarding a potential road pricing scheme in Auckland, New Zealand.

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## **Preface**

This report was started in September 2008 in Wellington, New Zealand and was completed in Sweden in February 2009. Despite having experienced two cold winters in a row (both in New Zealand and in Sweden) the author has enjoyed researching and writing this challenging report and has found it of much interest. The report has been of extra interest to the author as the topic has been lively discussed in several cities throughout the world in the recent years.

The author would like to thank his supervisor Lena Winslott Hiselius for important and quick feedback and many good ideas. Furthermore, the idea to write about congestion pricing came up while working for the Road administration in New Zealand (Transit New Zealand). The author is grateful to have had this work opportunity that has been a great experience and has also helped to compare and understand different ways of road management. Lastly, big thanks to Carl Volckerts for his help translating Italian.

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Valfrid Jarl

## Glossary

Areas Scheme	Charge imposed when entering or driving within a tolled area.
Congestion Pricing	Direct measure to reduce traffic in order to reduce congestion. Used synonymously with congestion tax or congestion charge.
Congestion Charge	The term used in the United Kingdom such as in London & Durham. <i>See</i> congestion pricing.
Congestion Tax	Name of used measure in Stockholm. <i>See</i> Congestion Pricing
Cordon Scheme	Charge imposed when entering and/or leaving a charging area.
Marginal Cost	Change in total cost when the quantity produced changes by one unit.
Passage Toll	Toll levied every time a charging point is passed.
Road user charges, RUC	General charges on road users such as road pricing, fuel tax, license fees etc.
Road pricing, RP	Levy imposed on road users when driving on a certain road or area etc.
Revenue charging scheme	Road pricing scheme with main objective to raise revenue in order to fund other projects. Usually designed to have minimal impact on traffic.
Traffic Flow	Number of vehicles driving on a road link for a given period of time

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## Summary

The purpose of this report is to assess demand measures in order to manage urban traffic congestion. This report focuses on congestion pricing and compares it to other measures possible measures. The cities investigated are: Singapore, London, and Stockholm with congestion pricing schemes and Milan with a scheme designed to reduce pollution. Lastly, the key findings from the analysis and discussion of the cities will be used in order to contribute to the assessment of a road pricing scheme in Auckland, New Zealand.

Traffic congestion is associated with peak travel in urban areas. There are several causes behind this issue such as the rapid increase in car use at the expense of public transport, the lack of space in the cities and the intense traffic during peak hours. Furthermore, cars contribute more to congestion than public transport. One way of addressing the problem of congestion has traditionally been through supply-side measures such as traffic management or construction of more roads. New infrastructure is generally expensive in urban areas as it often requires complex solutions. Reducing congestion through an increase of public transport is generally inefficient as there is a strong preference for driving in a private vehicle, making few drivers wanting to swap. In addition, the effect of these measures (reduction of peak hour congestion) is only temporary, as the released road space tends to attract more traffic from other modes of transport, other roads or travel times.

Another way of managing congestion is by using demand-side measures. These measures affect a traveler's preference, through affecting the costs of transport-related markets. These can either be direct measures such as congestion pricing or indirect measures such as annual taxing on the vehicle, fuel taxes, parking fees or public transport subsidies. Congestion pricing manages traffic directly while the indirect measures only partly tackle the congestion issue. To achieve the same result, alternative measures would have to be more costly and affect other markets unrelated to congestion. Thus, congestion pricing is the most efficient measure in order to manage traffic. However, the measure is based on a theoretical model with simple assumptions while the real case is more complicated. Unless the revenue collected from congestion pricing is redistributed back to the road users, these are, on average, likely to be worse off. This states that the redistribution of the revenue is of high importance to achieve a successful scheme. There are additional concerns regarding traffic diversion and equity impact that needs to be addressed in order to minimize the possible impact. These are some of the reasons behind the fact that currently, only four schemes have been implemented in major cities and far more rejected.

The cities assessed in the report were analysed in chronological order according to the year of implementation: Singapore (1975), London (2003), Stockholm (2006 on trial, 2007 permanent scheme) and Milan (2008 on trial). The areas assessed were:

- Conditions before implementing the scheme
- Scheme design
- Traffic impact:
  - Inside and outside the zone
  - On public transport users
  - On residents inside the zone
- Equity and Business impact
- Implementation process

Considering the conditions before implementing the schemes, Stockholm and London had high mode shares of public transport and low numbers of car ownership. Singapore and Milan had small public transport usage and required either major public transport expansions and/or a scheme designed to affect less road users.

Regarding the effect on traffic flow, all schemes reduced congestion. The first scheme in Singapore saw the largest reduction (45%) in traffic during the morning hours. London, Milan and Stockholm with whole day schemes reduced traffic by 14%, 13% and 22% respectively. Singapore experienced new congestion outside the charging zone. In the other cities these impacts were lower, partly because of traffic management prior to the commencement of the schemes. Assessing entering traffic, all schemes saw new traffic peaks after the charging hours in the evening. Moreover, the traffic reductions were generally higher outside the morning hours suggesting that the fee could possibly be lower for these hours.

All cities extended their public transport fleet prior to the introduction of congestion pricing to meet the higher demand expected. Overall, the cities experienced positive effects in public transport. These effects were for example higher bus speeds, flexibility and better reliability.

Regarding impact on road users, those staying on the roads after the schemes were implemented, were on average better off in Milan while worse off in the other cities. However, in London and Stockholm these represented a small share of the morning commuters. As public transport was generally improved, those already on public transport before the scheme were the same or better off.

Direct impact on business activity has been low and businesses inside the charging zones have followed general economic trends. Overall, residents living inside the area were positive to the congestion schemes in Singapore, London and Stockholm (no info for Milan). In London and Stockholm most low income earners were on public transport before implementing the schemes. Thus, these were better off as public transport was generally improved. In Singapore there were no signs that low income earners were worse off than other groups. There is no information regarding this for Milan but car owners were generally better off.

The capital costs of the schemes were, in all cities but Singapore, partly or entirely financed by the central government, which likely reduced the financial issue among the public in the cities. Experience shows that public support tends to increase significantly after the commencement of a scheme. On the other hand, the same proposal is likely to be rejected, if a referendum/public consultation is held prior. Stockholm and Milan have revenue, environmental and traffic objectives. The first two objectives are likely easier to perceive by the public and likely to gain a higher support.

Overall, the cities show that congestion or environmental pricing is a viable measure to manage traffic and congestion. Furthermore, the concerns about the potential negative impacts, overall, have not occurred, or have occurred to a small extent. Experience also shows that congestion or environmental schemes can be adapted after the conditions of the city i.e. a city with high car usage and a share of low public transport can have more discounts and exemptions.

Regarding a possible implementation in Auckland, New Zealand, the Auckland road pricing evaluation study proposed five different congestion pricing schemes in 2006. Of these, two schemes were identified in this report as the most suitable schemes: a *Double cordon scheme* and an *Area scheme*.

The initial conditions in Auckland are similar to Milan in terms of low public transport usage and high car ownership. The scheme design has several features in common with Singapore such as:

- Charging hours were for morning hours only, assumed to reduce congestion in evening hours as well.
- A high number of the cars affected, were predicted to be tolled off
- A high increase of public transport would be required.
- The affected drivers represented a significant amount of the total car commuters

Singapore implemented the scheme with the most radical effects. Even though commuters today are better off in Singapore, such an implementation requires high compliance from the public. A similar scheme in Auckland is difficult to achieve, especially if a public consultation is required prior to any implementation. If it is possible to implement such a scheme, it is important to address equity issues, and provide a free alternative such as adequate public transport and/or a free bypass (for those not wishing to enter the charging area). As well, it is recommended that a congestion scheme in Auckland operates for hours outside the morning peak (if the intension is to reduce congestion for those hours too).

The transport authority in New Zealand is also considering a road pricing scheme with revenue as the first objective. This option is likely to get higher support from the public as its objective is easier to perceive than congestion. As the mode share is low for public transport in Auckland, even a small reduction in car use could increase public transport use significantly. As the traffic impact would be low, less preparation would be required and a revenue scheme could thereby commence before any of the congestion schemes.



# 1 Introduction

## *1.1 Background*

Congestion is a phenomenon associated with peak hour travel in the major cities throughout the world today. There are several measures to tackle this issue such as new roads and an increase of public transport. Congestion pricing is one of the latest measures introduced. On the one hand, the measure is likely the most efficient in order to reduce congestion. On the other, the measure is disputed and there are today only four cities with schemes to reduce traffic and far more that have been rejected by either the public or politicians. Why should congestion pricing be adopted despite this resistance and why cannot other measures be used instead for the same purpose? Are some cities better suited than others and is there any way to address the possible negative impact caused by congestion pricing?

In order to answer these questions the report will firstly assess the causes behind congestion, how it occurs and if traditional solutions such as construction of new roads and an increase of public transport can solve this issue. Secondly, congestion pricing will be compared to these and other possible measures in order to reduce congestion. Lastly, it is of high interest to assess the cities that today have adopted congestion pricing schemes or schemes to reduce traffic. These cities are Singapore, London, Stockholm and Milan. What was the effect on traffic, did the possible negative impact occur and how were these concerns addressed? Lessons learnt from these cities are interesting in order to introduce congestion pricing schemes in other cities. There is currently being assessed an introduction of congestion pricing in Auckland, New Zealand. The city will be compared to the cities with current schemes in the analysis and discussion chapters. Lastly, in the conclusions chapter, the objectives will be responded.

Economic definitions used in the report are further explained in Appendix A.

## *1.2 Purpose*

The purpose of this report is to assess the overall effectiveness and possible impact of congestion pricing as a means to manage traffic congestion in urban areas. What are the drivers behind congestion pricing and what are the benefits/disadvantages of this measure relative to other existing measures? What has experience regarding congestion pricing shown and what lessons can be learnt for other cities with traffic problems?

## *1.3 Objectives*

In order to achieve the above purpose this report has several objectives. The first objective is to identify the causes of congestion in urban areas as well as the effectiveness of existing supply-side

measures in relation to this (chapter 2). Secondly, congestion pricing and other possible demand-side measures will be identified and assessed in terms of efficiency (chapter 3). A further objective is then to assess why congestion pricing is not used to a wider extent today and the general concerns regarding this measure's possible negative effects (chapter 3). Another objective is to compare the theoretical findings of the above chapters to the practical findings of the cities where congestion pricing has been implemented. This is done by assessing the four cities today using schemes to reduce traffic (London, Milan, Singapore and Stockholm) in the following areas: conditions before implementing the measure, scheme design, effects on road users, the possible adverse impact on equity and the economy overall and lastly the implementation process (chapters 5 and 6). A final objective is to assess the lessons learnt from the case study cities in order to contribute to the current discussion of a possible road pricing scheme in Auckland, New Zealand.

## ***1.4 Methodology***

Firstly, the report identifies the causes and consequences of congestion in order to understand why congestion is a problem today. Secondly traditional measures such as road expansions and an increase of public transport will be assessed to measure their possible impact on congestion and if these measures can solve congestion alone. These and other measures will be compared to congestion pricing in terms of efficiency. Next will be assessed the possible adverse impact of congestion pricing and how this may affect the public acceptance of the measure. These areas are well known and described in literature from mainly Button (1993 & 1998), Bull (2004), Emmerink (1998) and Johansson and Mattsson (1994). As these areas already have been assessed, they will not be a part of the analysis in this report. The case studies part assesses cities with traffic reduction schemes today. With the exception of Singapore, the schemes are fairly new and most sources are either from reports issued by respective city's transport authority or from up-to-date papers from databases. The cities will be compared in the analysis and discussion sections in order to evaluate how they have corresponded to expectations and concerns in described in chapter 3.

## ***1.5 Limitations***

Supply measures to reduce congestion will be discussed in chapter 2, but not further assessed in the case studies chapter. This report focuses on large cities and minor cities or specific tolled lanes will not be evaluated as the impact is limited. Little will be said about road pricing with the primary objective to raise revenue, as this scheme is usually designed to have minimum impact on traffic. However, a new scheme in Milan, *Eco Pass*, with the main objective to reduce pollution, will be assessed in the case studies chapter, as this is likely to affect the traffic pattern. There is (non recurrent) congestion that occurs due to bad weather or accidents, however, this report focuses on (recurrent) congestion that generally appears in peak hours. Lastly, there will be no evaluation regarding the cost of schemes, technology or the possible effects on accidents.

## 2 Causes of congestion and supply-side measures

This part commences with a brief explanation of how congestion occurs followed by possible definitions used in order to measure and quantify congestion. Furthermore, it will be explained the effects of congestion and the causes behind it. Lastly will be assessed the possibility of reducing congestion through increasing road capacity or by expanding public transport.

### 2.1 *The Relationships: congestion, density, speed and cost*

Traffic can up to a certain level, flow on a relatively free speed which is dependent on the speed limit, number of intersections etc. At higher levels of traffic, vehicles start to interfere with each other; the higher the level is the more likely vehicles are to affect each other. An illustration can be made with two figures from Hau (1998, p. 43-44). The first (Figure 1), illustrating the relationship between speed and density (vehicles/km) on an urban highway where vehicles can travel up to the speed limit ( $S^{\max}$ ) on the road to a certain point of density. After that, as the density increases, the average speed will decrease. It reaches maximum flow  $F^m$  at  $D^m$ . Similarly, Figure 2 shows the relationship between speed and flow where the average speed is first unaffected with an increasing flow until a given point. After that, as another vehicle enters the road, the whole average speed will decrease. Note that after the point  $F^{\max}$  is reached, both the average speed and flow reduce when more vehicles enter the road.

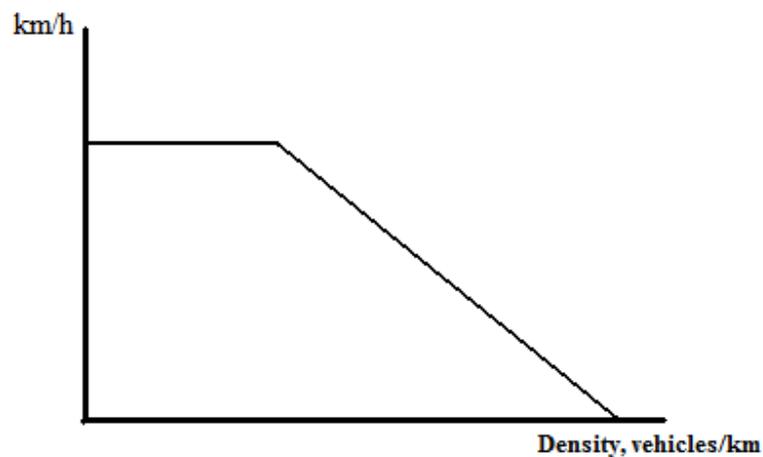
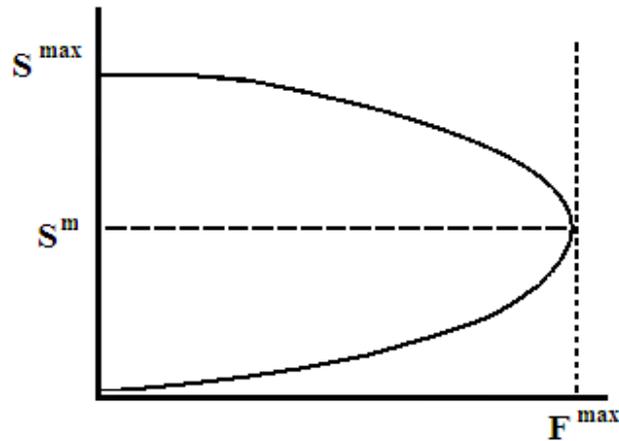


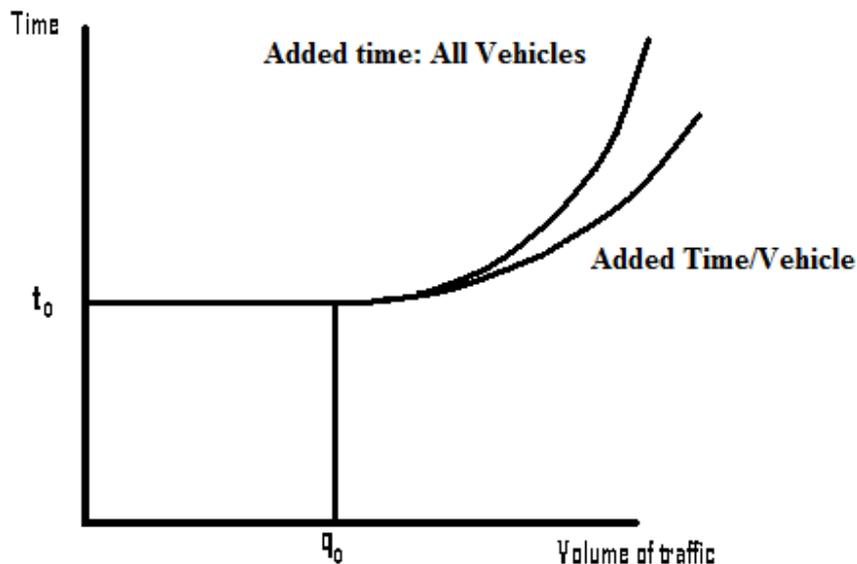
Figure 1 – *The relationship Speed Density* (Hau, 1998, p.43, figure 3.1a)



**Figure 2** – *The relationship: Speed Flow* (Hau, 1998, p.44, figure 3.1b)

Another observation in Figure 2 is that the flow not only reduces but decelerates when more additional vehicles join the road after that  $F^{\max}$  is reached. (Hau, 1998, p. 43-45)

This effect can be more clearly illustrated with Figure 3 which shows the relationship between the trip time for an additional vehicle and the total extra time it causes on other vehicles. One observation is that, at small levels of traffic the total increase of travel time is only caused by the additional drivers travel time, whereas at higher levels, these two curves diverge, due to the extra delay caused by the additional vehicle on others. A second observation is that at small levels of congestion, an increase of traffic flow does not increase the travel delay significantly, but at higher levels the same increase causes a high marginal increase of travel delay (Bull, 2003, p.24-25)



**Figure 3** – *The delay caused by an additional vehicle on other road users.* (Adapted from Bull, 2003, p. 24)

## 2.2 Definitions

Similarly from previous examples, Thompson and Bull (2001, *cited in* Bull, 2003, p.23) define congestion as “the situation where an additional vehicle to a traffic flow, increases the journey times of the others.” Traffic for London (2003) defines congestion as the average excessive time spent under congestion. Excessive time in its turn is the time above that under uncongested condition, i.e. free-flow conditions. Mathematically this would be defined as:

$$\text{Excessive Time} = \left( \frac{\text{Time}}{\text{Distance}} \right)_{\text{Congestion}} - \left( \frac{\text{Time}}{\text{Distance}} \right)_{\text{FreeFlow}}$$

Congestion is defined as min/km. The same method is used in Stockholm (City of Stockholm, 2006d) Milan uses a different approach by summing up all distances in a road network with a ratio flow/capacity ratio exceeding 0.9:

$$\sum IF \left( \frac{\text{Flow}}{\text{Capacity}} \geq 0.9,; \text{"Distance of link", " 0"} \right)$$

Thus, congestion is defined as “km” of roads with a share exceeding 0.9. (Milan Council, 2008)

## 2.3 What are the consequences of congestion?

Congestion leads to higher operational costs for the road users and also causes externalities that are more difficult to quantify in terms of waste of time and environmental pollution. (Button, 1993)

This section briefly describes who suffers from congestion and how.

The extra costs caused by an excessive road usage can either be suffered by the road users themselves or costs imposed on others (non-road users). For the road users, congestion causes two types of costs:

1. Costs associated with a time loss.
2. Operational vehicle costs, e.g. higher usage of fuel.

The time value and operational costs affects commuters (cars and in this case, public transport) as well as companies. By making activities more expensive congestion adversely affects a city’s efficiency and its competitiveness. (Bull, 2003)

Furthermore, congestion holds up buses and reduces the number of trips they can make and, overall, reduces their capacity. The higher costs may at the end be reflected in higher bus fares.

However, congestion does not only harm the road users themselves but also worsens external effects such as air and noise pollution suffered by the city dwellers (Bull, 2003) These arise from the uneven speed flows caused by cars stopping and starting and overall slow speeds that are less efficient than the design cruise speed. (Button, 1998) Thereby, congestion also worsens external

effects on a regional and on a global level. However, its effects are particularly severe on a local level as congestion tends to occur in urban areas. (Button, 1993)

## ***2.4 Causes of Congestion***

What are the causes behind congestion and why is it a problem in many urban areas today? This chapter will look at congestion as a phenomenon consisting of several characteristics. Driver's behavior as a contribution to congestion will be discussed later in the report and not in this chapter which, mainly focuses on the fundamental causes.

### **2.4.1 The increased use of private vehicles**

Vehicle growth is usually related to income and countries with higher mobility generally have higher GDP. (Button, 1993, p. 18-19)

Dargay et al. (2007), assesses the relationship between annual growth in GDP per capita and vehicle growth per 1000 inhabitants in 45 countries, representing 75% of the world's population. The report concludes that between 1960 and 2002 at levels of \$3000-\$10000 the vehicle growth was twice as much as the per-capita growth. This is where Europe was in the 1960's and where many developing countries, especially in Asia, are now and will experience for the next two decades. At higher levels the growth is slower and finally reaches its saturation level which is now the case for most OECD countries. (Dargay et al., 2007)

Among the 21 European countries that were assessed, 19 had less than a 135 vehicles per capita in 1960. The countries average vehicle growth was more than twice (5.4%) the income growth (2.6%) between 1960 and 2002. With the exception of Turkey, all European countries had more than 300 vehicles per capita 2002 and all western European countries were above 430.

The report states that the vehicle fleet of the world in 2002 was 800 million and was predicted to increase to 2 billions in 2030.

Moreover, not only car ownership has increased but also the usage. During the 1980 and 1990 the vehicle ownership per capita in the USA grew with 14.3%, the number of kilometers driven per vehicle increased by 28.4% and at the same time the population of the USA grew with 24.2%. Multiplied together this means that for an average American town in 1980 the total traffic would have increased by 82% ten years later, which corresponds closely to the actual increase (80%) of total km's driven in the United States. (Downs, 2004)

Low land density (Downs, 2004) and governmental policies towards car ownership (Bull, 2003) are other factors that have contributed to the increased ownership and usage. However, this report will not assess the causes any further, merely wants to show that car ownership has risen significantly over the last four decades.

## **2.4.2 Cars cause more congestion than other vehicles**

Cars cause more congestion than other vehicles. In order to compare how much vehicles contribute to congestion relatively, each type of vehicle can be assigned a passenger car unit (pcu). A private car is equivalent of 1 pcu while other vehicles have a number according to their disturbance on the traffic flow and the space they occupy relatively to cars. A bus is generally assigned 3 pcu's and a truck 2. Thereby, a bus as a vehicle causes more congestion than a car. On the other hand, a bus can carry more people. If a car on average carries 1.5 passengers, a bus will contribute less to congestion as long as it carries more than 4.5 people. Assuming that it carries 50 people during peak hour a bus would contribute 11 times less than a car to congestion. (Bull, 2003, p.27)

## **2.4.3 A problem in the cities**

### **2.4.3.1 Lack of Space and city growth**

Living in cities brings a range of satisfaction that people value high. These satisfactions are more closely situated in cities than outside. The fact that houses, industries, education, entertainment are all closer together, creates a scarcity of land and a high demand reflected in its price. The efficient use of land is therefore of a major concern in cities. (Hibbs, 2003) Transportation infrastructure is no exception and competes with other forms of built environment in a city. (Johansson & Mattsson, 1994, p.18) Thus, transportation capacity in an urban environment is generally limited, and requires complex and expensive solutions to increase its capacity. (Bull, 2003, 26)

Other reasons may be growth in population or economic activity which may lead to higher transport demand in the city overall. (Downs, 2004)

### **2.4.3.2 Recurrent and non recurrent congestion**

A feature in urban areas is the strong variation in the traffic flow during a day (Johansson & Mattsson, 1994). Since traveling is a derived demand; its pattern is dependent on other patterns of activities with the demand associated. This, in some instances creates recurrent high demand at certain times, e.g. peak hour demand in mornings and evenings reflecting commuters going to and from work. (Cole, 1998) The cost to satisfy peak hour demand in combination with the lack of space is extremely expensive. (Bull, 2003, p.26)

There is also congestion that is non-recurrent and can be related to different events. They are caused by incidents such as accidents or bad weather. According to Lindley (1986, 1987, 1988, 1989 *cited in* Emmerink et al., 2000) non-current congestion accounts for 60% of the total congestion delay. However, this figure would not be “nearly as large” if roads were not already overloaded due to the recurrent congestion. (Emmerink, 1998, p. 31)

### 2.4.3.3 The effect on Public Transport

As earlier described in this report, there has been a strong car growth in second half of the 20<sup>th</sup> century that has resulted in more cars on the urban network. However, the increased popularity of owning a car has done so at the expense of urban the public transport. Button (1993) uses the following example of a typical progress in many cities after 1950s. The city is assumed being concentric with work locations in the central area, surrounded by residential areas:

- First phase: Everyone commutes in a bus – taking 10 minutes
- Second phase: 1 person buys a car, and reduces his travel time to 5 minutes without changing the travel time for the persons remaining on the bus.
- Third phase: Inspired by the first person's better social situation, more people purchase cars resulting in congestion and a travel time of 15 minutes for car commuters and 25 min for bus commuters. Longer journeys for the bus and fewer passengers lead to higher fares and may eventually cause a withdrawal of the bus line.

## 2.5 Supply Side Actions – Capacity Increases

This section investigates possible supply side measures in order to reduce congestion. These are measures that result in more road space released to the road users such as construction of new roads, better traffic management or making more people swap to public transport by extending its capacity. More possible measures are presented in Appendix B.

The following chapter will be discussed from a “congestion point of view” and it should be stressed that even if a measure is unable to reduce congestion, it does not necessarily mean that it is not good in socioeconomic terms. Capacity increases generally means that it makes the rush hour period shorter, and more people can travel when they want. (Bull, 2003)

### 2.5.1 Extra Road Capacity and Downs' Law

Congestion has in the past been seen as a shortage of capacity to meet prevailing demand. The traditional response has been to build more capacity. (Button, 1998) Generally, the first option considered is the enlargement of intersections or additional lanes. These methods are, however, usually very expensive, especially if they are built in order to satisfy peak hour demand, (Bull, 2003) There are other methods of increasing the traffic flow based on the way traffic is managed, such as synchronization of traffic lights on a street or providing information. (Bull, 2003)

However, even if an increase of transport capacity will reduce congestion in short term, it tends to encounter Downs' "fundamental law of traffic congestion" which implies that “due to latent demand, traffic will rapidly increase to meet an expressway expansion in urban areas, resulting in excessive congestion” (Hau, 1994, p.224)

Downs (2004, p.82) calls this “*The principle of triple convergence*”, which means that a capacity improvement will make drivers switch from other roads, times and means to the new/improved

road. Thus, the traffic reaches a new equilibrium but the improved road is still congested. One example is the Amsterdam Ring Road, where a large number of drivers that used to go to work either before 7.00am or after 9.00am changed to a more convenient time within the time range after that the Ring Road was completed. (Emmerink, 1998, p.41)

In the short run, a capacity increase is likely to shorten the peak hour time. In the long run, the new road expansion might attract more people to travel and firms to move closer to it. This induced demand might add enough traffic that causes congestion even worse than it was initially (Downs, 2004, p.104) In fact, experiences show that in cities that built numerous urban highways (e.g. Los Angeles) have made it so attractable for cars that the congestion has become even more unmanageable. (Bull, 2003, p.82) Thereby, increased road capacity tends to be filled out (Johansson & Mattsson, 1994, p.18)

### **2.5.2 Public Transport and the preference for cars**

A measure for giving priority to public transport is by offering exclusive lanes or streets. By doing so, the relative travel time compared to cars improves and might attract road users to swap to other modes. Examples from Santiago de Chile show that some bus routes decreased their journey times by up to 37%. As mentioned earlier, increased bus capacity may decrease the operational costs and at the end, influence the bus fares. Another advantage is the relative low cost to implement this measure. (Bull, 2003, p.66)

Subways have existed in the world biggest cities since the mid 19<sup>th</sup> – century (Bull, 2003). This measure is efficient as it does not compete with the road users, thus, it does not suffer from congestion caused by other means of transport and can operate at a high rate of capacity. However, there are a few disadvantages from implementing railroad and subway systems. Firstly, they are very expensive to build.

Secondly, even if both subway and bus capacity measures make the journeys more efficient and make the travelers already using these means of transport better off, they do little to reduce congestion. (Bull, 2003) One reason is the strong preference for car usage relatively to public transport. When competing between cars and public transport it is not only the relative travel time which influences a travelers preference, but also frequency, reliability, amenities, security, possibility of carrying cargo etc. (Johansson & Mattsson, 1994, p.47; Bull, 2003, p.76)

Allport and Thomson (1990 *cited in* Bull, 2003, p.76) made a study on mass transit systems in developing countries and conclude that immediately after that a subway was opened, 81% percent of its passenger were previous bus passengers, 16% were passengers that didn't use to travel on the axis and 3% switched from car or motorcycle. Even though Bull (2003, p.35-36) argues that it is harder to make drivers switch from car to public transport in Latin countries than developed countries,

facts presented by Goodwin (1992 *cited in* Button, 1998, p.120) show that the cross-elasticity between car and public transport, overall, is not very high.

Similar to what happened in the Netherlands (Chapter 2.3.1) after the new ring route was built Bull (2003) gives the following explanation for what may occur when a new subway line is opened up.

- 1) The opening of a new subway attracts many former bus passengers
- 2) The transfer from bus to subway reduces the demand for public transport that will reduce its supply, especially during the peak hour.
- 3) The released road space, will be used by drivers that used to leave either before or after the peak hour.
- 4) The few that switch from car to public transport, release road space which is taken up by other citizens switching from public transport to car.

Therefore, an expansion in public transport capacity does not necessarily reduce congestion.

### **2.5.3 The quality of life**

A general restraint for many of the supply measures, is the lack of space in the cities. With the exception of subway, a capacity increase of a road or an extra bus lane requires space which is taken from something else. Houses might have to be removed, sidewalks reduced or green areas used by citizens for recreational activities taken away. At the end these capacity measures will affect the quality of life for the citizens. Thus, there will always be a balance “between mobility and habitability.” (Bull, 2003, p.47-48) A new motorway in an urban area can cut a local community in two and create a barrier between two communities with long established social ties and, on occasions, making it difficult for people to benefit from activities of the other side. (Button, 1993, p.109)

## ***2.6 Key Findings for chapter 2***

Congestion occurs when a traffic flow start reaching the capacity levels of the road. After a certain level of traffic, vehicles start interacting with each other, resulting in reduced speed. The excessive time spent on the road due to higher traffic is the definition of congestion in cities as London and Stockholm. Congestion causes increased time and vehicle cost on the road users. In addition, it contributes to air and noise pollution, thus, affecting the life of the city dwellers.

Congestion is a phenomenon associated with:

- Rapid growth in car ownership and car usage at the expense of public transport
- The fact that cars contribute to congestion more than public transport
- A problem in the big cities due to
  - Lack of space
  - Recurrent travelling in morning and afternoon
  - Rapid growth in population or economic activity

Supply measures expand transport capacity for the means of transport associated. However, these measures are often expensive and they tend to encounter Downs' law which states that extra road space through a capacity increase tends to be filled out. Public transport measures do little to reduce congestion as cross elasticity between car and public transport is low and by the fact that the new space freed up may be taken up by other cars. Another problem with capacity increasing measures is the lack of space which eventually will affect the citizens and the quality of life.

According to Smeed (1964, *cited in* Johansson & Mattsson, 1994, p.19) given that the employment is based in the center of a city, it is impossible to satisfy all demand for car travel in a region. In other words, congestion cannot be removed by investments in road capacity only. Therefore, there is a need of measures such as control over the traffic intensity. (Johansson & Mattsson, 1994, p.19)

### 3 Demand-side measures

So far, it has been discussed the causes of congestion and why supply measures cannot solve the congestion problem in urban networks alone. From now on, the report will assess possible demand measures and how these affect the traffic demand. In order to do so, the report will firstly illustrate how the traffic pattern is affected by the users' behavior and the change in traffic demand from the imposition of tolls. Lastly, chapter 3 assesses why congestion pricing is difficult to implement and possible policy measures that could be implemented in order to meet the concerns raised by different groups.

#### *3.1 Theory of congestion pricing*

Even if tolls have been levied for long, the purpose of doing so is not always the same. Road pricing is usually a way of paying back a debt financed road. Charging for congestion has a different purpose even though it may be perceived by the users in the same way. The following examples will show that road pricing has a different impact on traffic and benefits to a society, depending on the initial conditions of the road i.e. congested or not. The examples also illustrate how congestion occurs from “a behaviors point of view”. Lastly, an example will illustrate that a toll may not only affect the road usage but may also have other long-term impacts on a society. For more explanations regarding externalities and marginal costs, see Appendix A, “Externality”.

##### **3.1.1 Uncongested bridge**

Assume that a society is divided by a river and there is only one bridge that the inhabitants benefit from. If the bridge is uncongested, the tolls that possibly could be collected can never be as big as the total value to society if the bridge is untolled. Figure 4 illustrates this where the y-axis represents the total cost for the society and x-axis denotes the total traffic flow.  $c$  represents the vehicle costs which marginal costs are assumed being 0 as there is no congestion. If there is no toll, the total benefit to the society is the area (A-C-E). However, if a toll is introduced, the consumer surplus and the money collected from the toll are represented by the area (A-B-D-E), but at the same time, there is a welfare loss which is the area (B-C-D), due to the reduction of demand. Thereby, “there are no efficiency or welfare arguments that support charges for an uncongested bridge”. (Johansson & Mattsson, 1994, p.1)

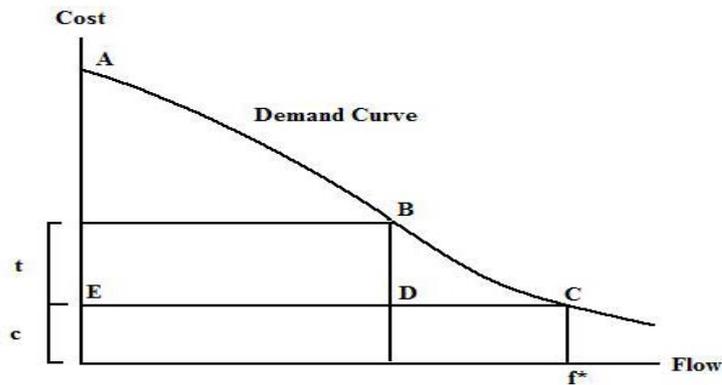
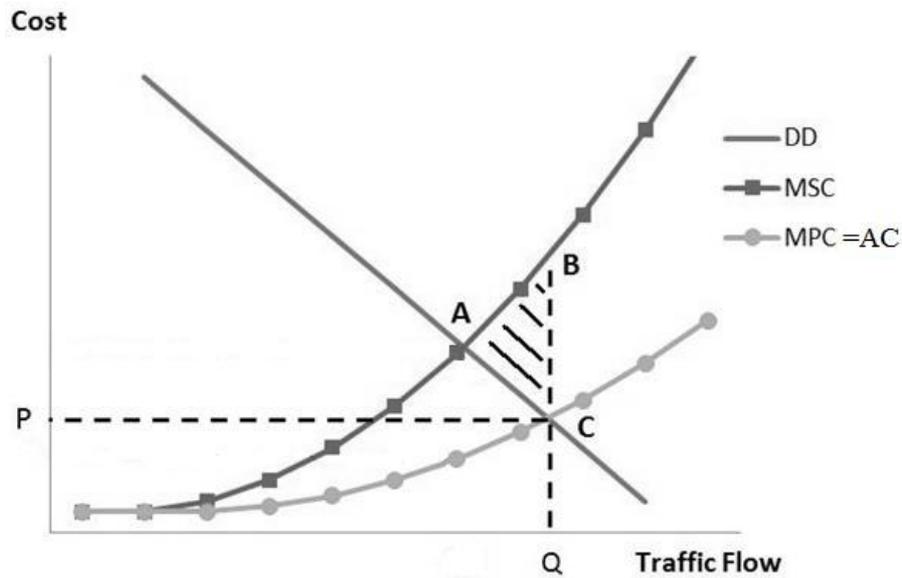


Figure 4 - The welfare loss if an uncongested bridge is tolled. (Johansson & Mattson, 1994, p.11)

### 3.1.2 Congested bridge

If the bridge in the example given in the previous paragraph has a higher car usage, (i.e. cars per hour) the vehicles will with an increasing flow start to interact with each other. The more cars that enter the bridge, the more impact they will cause on the cars already existing; reflected in terms of time loss and higher operational costs. In other words, the marginal costs for all vehicles increase for every additional vehicle that enters the bridge as congestion occurs. (The term “marginal costs” reflects to variation in costs, for different traffic volumes, see Appendix A, “Externality”).

Figure 5 illustrates this where the x-axis is the traffic flow and y-axis represents extra costs for an additional vehicle. The Average Cost (AC) curve represents the average time value and average operational cost for a vehicle and is equal to the Marginal Private Costs (MPC). This means, that the extra costs imposed by an extra vehicle, is shared by all drivers on the road. The Marginal Social Cost (MSC) curve reflects the total extra costs imposed by an additional vehicle. At small levels of traffic an additional car does not impose any extra cost on other cars and the marginal social costs are the same as the marginal private costs. However, with an increasing traffic flow, the marginal social cost curve starts to deviate from the marginal private cost curve. The more vehicles that enter the road, the more the marginal cost curves accelerate. (Button & Verhoef, 1998, p.5)



**Figure 5** – Without tolling, the flow will be obtained where the average cost curve intersects with the demand curve (A). (Button, 1993, p.114)

Without a toll the traffic flow will be where the average cost curve cuts the demand curve, (A) causing a welfare loss equal to the triangular area (A-B-C) shown in Figure 5. (Emmerink, 1998)

An external effect occurs when an actor is affected by another actor, not taking this external effect into consideration when making his decision. When driving on a congested road, a driver not only experiences a longer travel time himself, but also imposes further delays on the other road users. This is not taken into consideration by the driver which causes the externality. (Emmerink, 1998, p.38)

If a toll ( $t$ ) is levied, the road users will pay a toll on top of their marginal private costs (MPC). The toll that makes the total price on the road users ( $MPC + \text{Toll}$ ) equal to the marginal social costs (MSC) is called the optimal toll ( $t^*$ ). Thereby, the optimal toll  $t^*$  is:

$$t^* = MSC - MPC \quad (\text{Equation 1})$$

With this relationship, the new traffic flow is where the demand curve cut the MSC curve giving an optimal flow ( $Q^*$ ) which is shown in Figure 6. (Button, 1998)

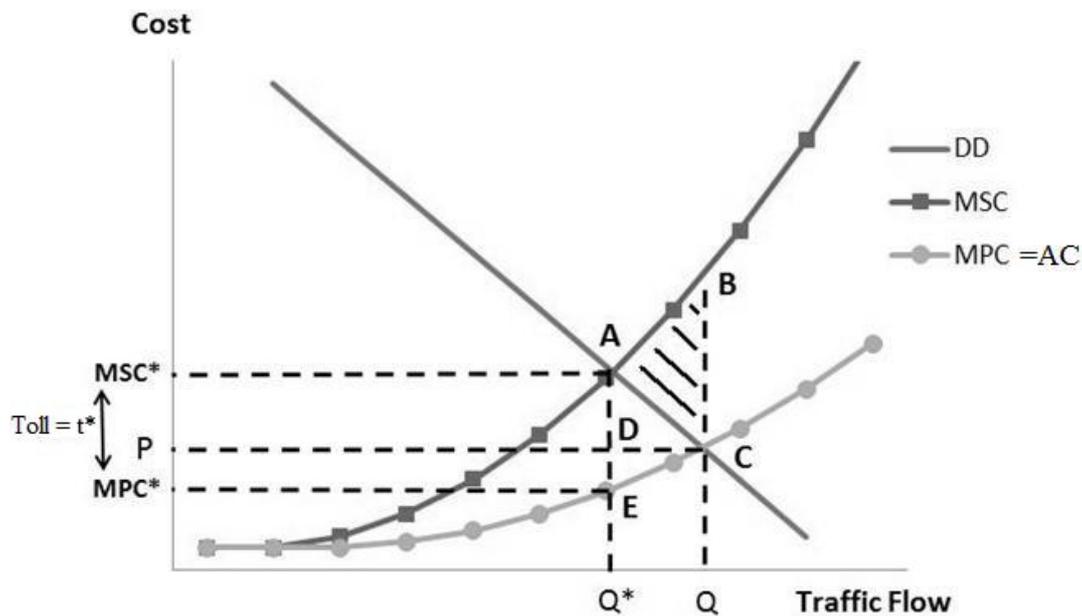


Figure 6 – Congested Bridge with optimal toll.

(Button, 1993, p.154)

By levying an optimal toll on the users of the congested road (equal to the difference between marginal social and private costs) the congestion externality is internalized which means that the negative impact on the other users are considered by the drivers when joining the road. (Emmerink, 1998)

### 3.1.3 Tolling in Urban areas

So far, the given examples have been based on simple assumptions. However, in urban environments there are more alternative roads, and houses and jobs are located in different areas creating a network with several destinations and origins. One important distinction to make is the difference between user equilibrium and system optimum.

#### 3.1.3.1 User equilibrium and System optimum

Wardrop (1952 cited in Johansson & Mattsson, 1994, p.20-21) made the distinction between two principles in transport network: the user equilibrium and the system optimum. According to the former principle, the road user will choose a route to minimize its cost. Thus, all used routes between an origin and destination (O-D) are cost minimizing routes. The second principle is the system optimum which is achieved when the traffic flow in a network minimizes the total costs. However, a system optimum does not generally arise naturally. For example, in a congested network the traffic flow is not necessarily cost minimizing for the system even though the users' choices are based on cost minimizing decisions. The reason for this is that in a system optimum, there are

generally O-D pairs with different costs. If this is the case, drivers in an optimal system are likely to switch to less costly routes, thus, breaking the system optimum.

The economic solution is to create a network with system optimum created by a user equilibrium flow pattern. This is achieved by tolling certain roads such that the system optimum can be achieved through cost minimizing decisions. (Johansson & Mattsson, 1994)

### **3.1.4 Relocation of activities**

So far it has been shown that tolls have an immediate response in terms of traffic pattern. However, in long term, there are possible impacts on the society too. Johansson and Mattsson (1994) give the following example: A society is divided by a river and there is only one bridge crossing it and there is no excess of labor. If there are households and job locations on each side, there will be a traffic flow between the jobs and the household on the same side and between the jobs and households on the other side of the river. If a toll is imposed on the bridge the traffic flow is likely to decrease. If there were different conditions initially for each side of the river in terms of wages, labor force or number of households the traffic flows across the bridge will be affected differently and a new situation will be created with a higher demand for jobs on one side and job vacancies on the other.

Following adjustments to this situation are possible:

- Jobs are relocated from one side of the river to the other side
- Wages on one side of the river, go up relatively to the wages on the other.
- Houses are relocated from one side of the river to the other.

This shows that a toll not only has a short term influence on traffic, but also has long term effects on other markets. (Johansson & Mattsson, 1994)

## ***3.2 Models of road user charging***

This chapter discusses different ways of road user charging. The following measures are generally differentiated in two groups. The first group, *direct measures*, achieves an optimal flow through restrictions or by levying an optimal toll. The second group, *indirect measures*, affects congestion by affecting costs that are associated with car use and car ownership. Lastly, congestion pricing will be compared to the other possible measures in a brief summary.

### **3.2.1 Direct measures**

Direct measures can regulate the traffic flow for a given time and space, thus, obtaining an optimal flow without affecting car usage in general. These can either be market based (congestion pricing) or restriction based in terms of achieving the desirable traffic flow.

### **3.2.1.1 Congestion pricing**

The direct measures of congestion pricing make the road users pay a toll for using a congested road or for entering a congested area. Drivers that previously used the congested road will use alternative roads (if there are alternatives), other times outside the peak hours or other modes of transport. (Downs, 2004)

Even though the toll generates revenues, it is firstly a method to make the road users aware of its contribution of congestion on a road. Secondly, being a market based measure; the users with highest value of time will use the road.

Thus the imposition of tolls on a congested road is first of all an instrument to create these benefits. As a direct method, it penalizes the perpetrators when and where congestion would appear without tolling, which is different to most other alternative measures described later. Furthermore, it creates revenues by taxing externalities. This is different to most other taxes that are imposed on productivity. (Emmerink, 1998)

### **3.2.1.2 Restrictions**

Restriction measures means that a certain number of vehicles are prohibited from entering a city. This can be achieved by issuing permissions to a certain number of cars. Thus, similarly to congestion pricing, an optimal flow can be achieved. The main difference is that the measure is based on a fixed number of permissions and not market based. Thereby, it is unlikely to yield the same benefits as congestion pricing as the permissions would not always go to those who gain the greatest benefits. Moreover, it requires a cost instead of generating revenue, thus, it is not self financing.

Restriction schemes have been tried in various cities around the world. An alternative approach to permission is restricting cars by their last digits on the number plate or by odd/even numbers. However, experiences from Athens and Mexico City are that many drivers purchase a second old vehicle to get around the restriction, thus, the vehicle fleet grew older. (Button, 1998)

## **3.2.2 Indirect measures**

Most of the methods presented below are commonly used today in order to regulate car usage. In this report, these measures will be called “indirect” in order to reduce congestion as these generally impact other areas of cars usage as well.

### **3.2.2.1 Parking charges**

Parking charges would similarly to road pricing, allocate scarce space to the road users by changing the amount of car spaces or increasing the parking rates, which indirectly would affect the traffic demand. However, this measure probably generates an improvement but not an optimal flow. (Button, 1998) One problem is that parking charges only penalizes the stopping traffic and might even encourage through (non-stopping) traffic which counts for approximately 50%. (Hau, 1994)

Another problem is the high amount of private car spaces. In the US, about 90% of the commuters park for free at work. (Willson and Shoup, 1990 *cited in* Button 1998, p125)

Even though parking charges is relatively cheap to implement, parking offences tend to be avoided unless high (and costly) enforcement is carried out (Button, 1994).

Joseph (1990) estimated that of 150 000 parking offences in London, some 149 000 go undetected. (Button, 1998, p.129) And many of those caught do not pay the fines.

These reasons make parking schemes a measure that cannot tackle congestion alone. However, Button (1994, p.43) stresses that a parking policy “must accompany any optimal road pricing scheme”. (Button, 1994)

### **3.2.2.2 Annual license fees**

In most countries it is common to impose an annual license fee to permit traveling with a vehicle. By varying the fee, the number of vehicles on the road can be regulated too. This system has the advantages of low transaction and administrative costs, especially if the license fee already exists. The disadvantages are that it does not charge the user for the amount of usage, for when and where it is used, thus, have little impact on congestion. (Button, 1998) Besides, there is a risk that once the fee is paid, it will encourage to travel more. The effects would be similar with a purchase tax on the vehicle. (Hau, 1994)

### **3.2.2.3 Fuel charges**

Higher fuel usage and congestion are correlated in terms of slow speeds that are engine inefficient and a traffic pace which involves frequent starting and stopping. (Button, 1998) However, fuel tax affects the amount of travel and is ineffective in dealing with congestion. (Hua, 1994) Even if it increases the fuel usage under congested conditions, road users have in practice a poor knowledge of their marginal private cost. Secondly, in longer term, a fuel tax is likely to increase the production of fuel efficient cars that benefit the environment rather than congestion. (Button, 1998)

### **3.2.2.4 Public transport subsidies**

Public transport can be subsidized in order to transfer car users to less congestion causing modes of transport. The method could be viewed as the opposite to a tax where the perpetrator of a negative externality is bribed (instead of levied a tax as in congestion pricing). With an appropriate subsidy, it is possible to reduce the level of traffic to a social optimal level.

Even though this measure is widely used, there are several objections. First, conversely to congestion pricing, it requires a cost that the taxpayers suffer rather than the perpetrators of congestion. This might affect other allocations in the tax system negatively. Secondly, to obtain an effect that is still relatively cheap, the cross-elasticity of demand between the different modes of transport must be high. However, according to studies made by Goodwin (1992 *cited in* Button, 1994, p.46) this is proven to be highly inelastic. Another problem is the possible latent demand for the road use, which means that the free road space is filled up with new traffic according to Downs' law.

Furthermore, subsidies may affect the efficiency of the public transport companies and there are other aspects than the price that are important in the quality of public transport service e.g. frequency and reliability.

Transport subsidies may be used (as a second best instrument) where congestion pricing is not possible. They may also be of social importance in terms of income distribution. Finally, they have a political advantage in that they do not hit a certain group, like road users with congestion pricing, but benefit a certain group. This is probably a major reason why the measure so widely used. (Button, 1994)

### **3.2.3 Congestion pricing vs. alternative methods**

Most alternative methods capture only parts of the congestion issue, by tackling mobile related markets instead of tackling congestion directly. Moreover, similarly to road investments, some of them encounter *Downs' fundamental law of peak hour congestion*. In fact, the same goals could be achieved with a package of alternative measures as congestion pricing. However, these measures would have to be more extreme and costly without congestion pricing than they would be with. (Goodwin, 1994) Button (1998, p.31) claims that even if there are situations when alternative measures are more suitable than congestion pricing, in reality, "the suspicion" is that these measures are implemented on political reasons rather than economic.

Thus, congestion pricing remains as the only instrument that directly penalizes the perpetrators of congestion only. However, it is not viewed as a standalone measure and there will always be a need to integrate congestion pricing into a package with alternative measures. Thus, alternative measures are likely to be used as a supplement to congestion pricing. (Button, 1994)

### ***3.3 Why congestion pricing is difficult to implement in urban areas***

The theoretical benefits of a possible congestion scheme have been well known by economist for long. However, most attempts to implement congestion pricing have failed. Various schemes seen today were supposed to be implemented decades ago and some schemes never have (Jones, 1998).

Looking at last years, schemes proposed in Cambridge, Edinburgh, Hong Kong, Manchester and New York, all have either been shelved or rejected (Authors Remark). Congestion pricing is a disputed measure and there are concerns raised not only by economists but also by politicians and the public. This chapter will discuss these concerns and also presents possible policy measures in order to meet the concerns raised and increase the public support for congestion pricing.

### **3.3.1 A first-best or second-best model**

Congestion pricing is theoretically a first-best solution. By charging an optimal toll equal to the difference between marginal social and private costs, only the most efficient trips are undertaken. However, the theoretical model is disputed and there are several objections regarding its practical feasibility.

First, the theoretical model is a static model whereas the real model is dynamic with a traffic flow far from being constant. Second, the price should not be based on prevailing traffic levels, but rather on predicted. Incorporating this is complicated as the traffic levels are based on drivers' behavior, which in its turn is influenced by the price. Third, it's difficult to calculate the exact costs of the externalities that congestion causes i.e. the cost of pollution. Further, the economic model for road pricing assumes that marginal cost pricing is applied throughout the economy. If this is not true, a toll equal to the difference between marginal social costs and private costs will not necessarily achieve an optimal flow.

Fourth, the congestion price should be discriminatory as vehicles contribute differently to congestion. This might be difficult in practice. Fifth, the networks are more complex in reality than in the theoretical model which is based on a simple model with no traffic control. Sixth, the assumption on rational behavior based on cost minimization is disputed. (Emmerink, 1998)

With this information, congestion pricing might be seen as just a second best instrument which only can solve part of the congestion problem. (Emmerink, 1998)

Button (1994) however, argues that these arguments do not destroy the whole economic model but rather indicate that the reality is not as basic as the economic theories suggests. In addition, many of these arguments can also be raised against alternative measure to congestion pricing. Emmerink (1998) claims that congestion pricing is most likely not a first-best model in reality but may be expected to be closer a first-best solution than any other instruments.

### **3.3.2 The welfare impact**

From an economist point of view, congestion pricing solves the problem with the dead weight by imposing an externality corrective price on the road users, making the total price equal to the marginal social cost. As well, the city dwellers are better off through reduced traffic congestion and

less adverse environmental impact on the tolled area (Goodwin, 1994). Here is examined how congestion pricing affects the road users. These, generally represent three groups:

- The tolled: The road users that still use the road after the implementation of a road toll.
- The tolled off: The previous road users that switch to another mode of transport, route or time of travel.
- The tolled on: Those who remain on other modes of transport

In all groups all individuals are assumed to have an equal value of time. As illustrated in Figure 7, the total benefits are equal to the area (P,B,E,MP\* - A,B,C). The element (P, B, E, MP\*) represents time savings and reduced operational costs for those who stay on the road. The element (A,B,C) is the reduced benefit due to the traffic reduction (Q-Q\*).

For the first group i.e. “the tolled”, it can be seen that the value of time savings is equal to the area of (P,B,E,MP\*). However, this time gain is clearly exceeded by the toll paid by the users (MSC\*,A,E,MPC\*). (Button, 1993) Thus, even though some road users with high time values find themselves better off these are outnumbered by the users with lower values than the imposed toll.

The total price (Average cost + toll) is still less than the road users’ willingness to pay which is illustrated by the demand curve in Figure 7. Thus, the ‘the tolled on’ stay on the road even though they are worse off as a group after the imposition of congestion charges. (Hau, 1994a)

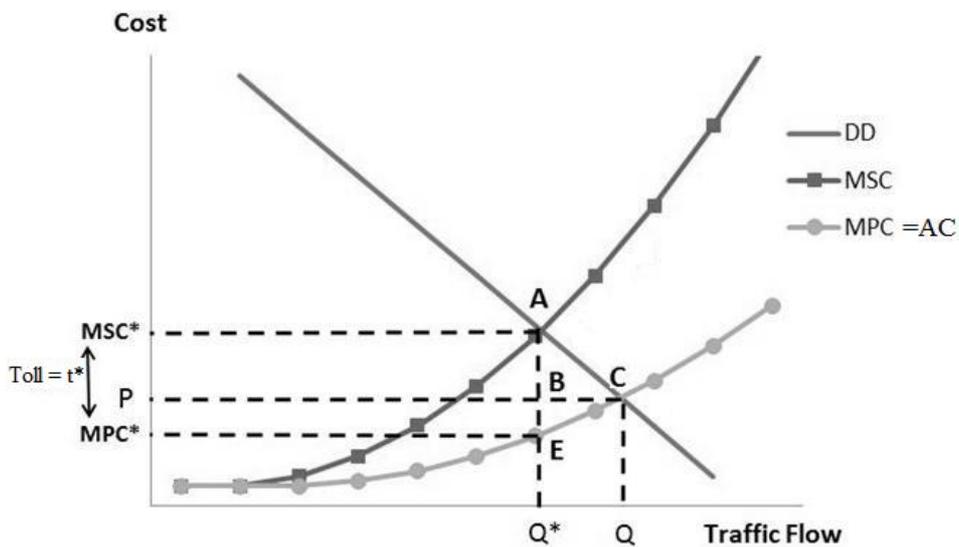


Figure 7 - The welfare impact by charging an optimal toll ( $t^*$ ). (Button, 1993, p.154)

The second group (“The tolled off”) is worse off as they are “forced” to switch to other times, routes or means of traveling. If another route is taken the commuter will incur higher vehicle and time costs, while switching to another time forces a change in behavior of the individual. Traveling

with another mode than car to work is generally less desirable. If public transport were seen as a more satisfactory mode of transport than private car, the traveler would have opted for that even without congestion pricing. (Hau, 1994a)

Those remaining on other modes of transport (“The Tolled on”) are likely to face a more crowded environment and longer stop times if the “tolled off” switches to public transport without seeing its frequency being expanded. This would make the tolled on worse off. (Hau, 1994a) As mentioned earlier; Bull (2003) claims that congestion affects both price and the bus fares negatively. Hau (1994a), states that in big cities with a high bus/car ratio, the time gains that occur with the decreased congestion is likely to offset the costs due to longer stops and crowded environment.

In conclusion, “the tolled” with a high time value and in some cases people on public transport are better off due to congestion pricing. However, these count for a small part of each group, which indicates that congestion pricing makes all three groups worse off. (Hau, 1994a)

However, there is a fourth group, the regulator (or the government). As a perceiver of the paid tolls, this is the only group that is better off. If the government does not redistribute the revenues to the affected parties, it is unlikely that neither affected group would support congestion pricing. (Hau, 1994a)

In conclusion, congestion pricing as an instrument to allocate scarce road space to those with the highest time value is not a strict Pareto improvement where everyone is better off. However, with the possibility of redistributing the revenues collected by the government congestion pricing leads to a potential Pareto improvement by satisfying the Kaldor-Hicks criterion. (Emmerink, 1998)

### **3.3.3 Further issues**

The previous section concluded that all three affected groups on average are worse off due to congestion pricing unless the state redistribute the revenues. However, there are a few additional problems:

The first concern is traffic diversion; reducing congestion on major roads might just divert it to other less suitable areas. (Button, 1993)

Secondly, congestion pricing will cause inequity by affecting lower income groups harder than other groups by tolling off those most sensitive to a price change. Further, congestion pricing will cause regional inequity by levying charges on certain areas or regions.

Third, it is difficult to predict how congestion pricing may affect land use patterns and also the productivity of certain sites. As earlier demonstrated, in short run a toll changes the traffic flow but long term effects can be relocation of e.g. houses and companies. Emmerink (1998) stresses that these effects not necessarily are negative but are important to predict.

Another concern is the possible treatment of congestion pricing as a pure tax by the government that could charge more than the actual marginal costs. Lastly, the overall costs for implementation and maintenance should not be underestimated. (Emmerink, 1998)

### **3.3.4 The public point of view**

Apart from the gains and problems viewed by economist there are further problems viewed by the public, whose opinion at the end will influence the outcome of whether congestion charges should be implemented.

Public attitude surveys have been carried out in various countries regarding charging for road usage in urban areas. Jones (1998) summarizes the public concerns raised in these surveys.

When first introduced to the concept about congestion pricing, many drivers react strongly against it. Firstly, people expect to pay for something they wish to obtain, not to avoid. Secondly, the perception of congestion pricing may simply be interpreted that people should pay for congestion. Related to this, most drivers do not see themselves as contributors of congestion but victims of it. (Jones, 1998)

Furthermore, there is the perception of the public that congestion pricing “is unfair”. This statement derives from two different opinions. The first is the view of a road as a public space, of which everyone has equal access to and is free to share. Secondly, since the objective of congestion pricing is to reduce traffic, those tolled off the road are the ones also least able to pay. Ability to pay and value of the trip are not always synonymous i.e. poorer people might need the car to go to work or visit sick relatives. (Jones, 1998)

Other arguments are the disbelief that the new technology will work, the privacy issue in terms of vehicle registration when entering a toll gate and that tolling is just another form of taxation. Lastly, there is a concern about the traffic impact outside the charged area i.e. what happens when drivers park their car or take other roads to avoid the charge. (Jones, 1998)

Seal (1993 *cited in* Emmerink, 1998, p.44) investigates the attitudes of politicians in London to congestion pricing where the analysis found several concerns. One concern is charging the drivers for using roads that until now have been free. (Emmerink, 1998) Even though transport is not free, transport studies have shown that car users have a poor knowledge about their marginal private costs in terms of being aware of the full costs of a trip. (Rietvald et al., 1998) Thereby, supporting congestion pricing might cost votes for the politicians (Seal, 1993)

The analysis also found a strong correlation between the knowledge of congestion pricing and supporting it and as well the fact that the public should not be allowed to view it as just another tax. (Emmerink, 1998)

Lastly, congestion pricing can be viewed differently by different interest groups. Politicians might see the increased revenues generated by the road charges, making it possible to finance infrastructure. Environmentalist might see the possible reduction in pollution due to the reduction in car use and business people may see the advantages of faster connections in the city. (Emmerink, 1998)

### 3.3.5 Policy

So far, it has been stated that congestion pricing is probably the most efficient measure to manage congestion. However, the measure is disputed and even if it is supported by economists there are a number of concerns raised by the public that has to be overcome before congestion pricing can be implemented. According to Jones (1998), these are:

1. Make sure the objectives of the scheme meet the public support.
2. The alternatives to congestion pricing are inefficient
3. Revenues should be redistributed and alternative provided
4. The scheme should be kept as simple as possible
5. Consider possible technological issues.
6. Equity concerns can be solved

The first point can be viewed from public surveys i.e. the percentage of people that are concerned about traffic congestion and/or pollution. For instance congestion pricing is likely to have a higher support in cities with higher problems of congestion (Emmerink, 1998). The second point has, similarly to the analysis by Seal (1993), a connection between support and knowledge about congestion pricing.

The third point is an area where drivers might have an interest. There is more resistance to paying “another tax” than paying for something with a clear goal. The fact that this issue is of significant importance has been argued earlier and is also stressed by Jones (1998). According to a study in the UK (Jones, 1991 *cited in* Jones 1998, p.276) assessing the public support for road pricing with and without revenue distribution the net support was 27% respectively -27%, where in the, former case the money would fund public transport, traffic safety and better facilities for pedestrians and cyclists.

Goodwin (1994) suggests that the distribution of benefits from congestion pricing should follow “the rule of three” which implies in broad terms that three different groups each should receive a third of the benefits. The two benefits that can be redistributed are:

- The release of road space
- The revenues received from the tolls

Of the released road space, one third should be distributed to each of the three following groups.

- Environmental improvement such as pedestrian areas and non-transport uses
- Improvement for specific traffic such as buses, freights, emergency services.
- Improvement for remaining traffic.

Of the received revenues one third should go to:

- Public transport improvements
- Improvements of roads
- General tax revenue (Goodwin, 1994)

The fourth barrier (The scheme should be kept as simple as possible) is important in order to make the system easy to understand, but also minimizes the risk for errors due to the technology used. However, it might also imply less flexibility of the system and users may not pay the accurate charge equal to their addition to congestion. Emmerink (1998) stresses that this issue is of more importance where congestion pricing encounters higher public resistance and recommends that a gradual implementation strategy is used in these cities.

The last issue is of major concern in countries with high car ownerships where cars are regarded as a necessity to meet the daily requirements. (Jones,1999) Kottenhoff and Brundell Freij (2008) claim that in cities with a high share of public transport there are less positive attitudes towards car driving, in their turn, these attitudes are likely to affect the attitudes towards congestion pricing. Gaunt et al (2007 *cited in* Kottenhoff & Brundell Freij, 2008) show that car ownership and car usage were important factors in the Edinburgh congestion charge referendum, were daily car users voted against and occasionally users voted for the introduction. (Kottenhoff & Brundell Freij, 2008)

Regarding the concerns of fairness, equity and the effect on the local market Jones (1998) gives some examples of possible actions to reduce/minimize the impact.

- All vehicle owners should be given free access to the charged area, i.e. there should be hours when no charge is levied. Additionally, people living within the area should have a number of free trips per month.
- In order to minimize impact on business within the charged area, there should be some free hours during business hours, or permit shops being open under uncharged hours e.g. later or on Sundays.
- High mileage vehicles should have higher priority than car commuters and shoppers. This can be achieved either by exempting some vehicles from charges or by having a maximum price that is relatively high for low mileage vehicles (but low for high mileage vehicles).

### ***3.4 Key findings for Chapter 3***

Under congestion the traffic level exceeds the optimal flow on a road network. The principal reason is that the drivers try to minimize their cost; however, these decisions are not cost minimizing for the network as a whole as the driver imposes an extra cost on the other road users. The drivers do not take these costs into account when joining the congested road.

Congestion pricing penalizes the perpetrators of the external effects during high traffic. Conversely to road expansion, congestion pricing adjusts the demand to the supply. Differently to most alternative methods it deals with congestion directly and is likely to be the measure most closely a first-best solution of all possible measures. The effect of congestion pricing is a reduction in demand, reflected by drivers tolled off to other times, roads or modes of transport. Through this approach (which is market based) the road network is utilized by the individuals with the highest value of time.

The groups likely to benefit directly from congestion pricing are the city dwellers living inside the charged area, road users with a high time value and in some instances people on public transport. However, in most cases road users are generally worse off as a group unless they are compensated. This is possible as congestion pricing generates revenue that can be transferred back to the road users. Thus, the likelihood of a acceptance by the road users is higher, the closer congestion pricing achieves a strict Pareto improvement rather than a potential Pareto improvement.

Overall, interpreting Jones (1998), some of the concerns by the public may be addressed by better information. On the other hand, there are a number of concerns remaining. Those, further assessed in the next chapter are:

- The impact on drivers and public transport users
- The possible increase of congestion outside the zone as an effect of drivers diverting around the zone
- City dwellers living inside the charging zone
- The impact on low income earners
- Business and land use affected

The initial conditions of the cities and the design of the schemes are vital in order to minimize the impact and to gain a higher support by the public.

## 4 Case Studies

This section comprises case studies of the four cities using congestion pricing today: London, Milan, Singapore and Stockholm. In Milan, the scheme is primarily designed to reduce pollution. However, as traffic reduction is one of the objectives, the possible traffic impact is still interesting when comparing the results with the other cities. Below is presented the specific fact to be identified to respond the objectives stated earlier in the report: the conditions in the city before implementation, scheme design, the traffic response of the scheme for road users and residents within the zone, equity and business impact and lastly the implementation process.

The key findings and lessons learnt will be analyzed and discussed in the following chapter and in order to recommend a suitable road pricing scheme in Auckland, New Zealand.

Below is a brief description of possible findings for the cities.

### 4.1.1 Facts about the city

What were the conditions in the cities before implementing the charges in terms of:

- General facts about the city, population and growth, density
- Car ownership per 1000 inhabitants
- Average Speeds & congestion
- Public transport/Car -mode share

### 4.1.2 Scheme

- Objectives
- Affected Area, size and number residents/jobs
- Variable charges: Time, Vehicle, Spatial
- Exemptions
- Free routes, ring roads

### 4.1.3 Effects

- The immediate traffic response
- Cars

- Modal Swap
- Public Transport
  - Flexibility
  - Average speeds
  - Punctuality
  - Commodity
- Business Impact
- Equity Impact
  - Road users affected
  - Citizens living inside the zone

#### **4.1.4 Implementation process and public opinion**

- Referendum or decision by local government
- Public impact on the scheme design
- Possible change in public support before and after commencing charges

## 4.2 Singapore

Singapore pioneered by introducing the first urban road pricing scheme in 1975 which is known as the Area Licensing Scheme (ALS) (Small & Ibanez, 1998). The small island nation, which contains the city with the same name, has one of the densest populations in the world. The 684 km<sup>2</sup> island nearly doubled its population from 1975 (2.3 million) to 2007 (4.35 million) giving a population density with more than 6000 persons/km<sup>2</sup>, where the built up area is more than half of the total land area. The economic growth has averaged 7 % for the same time and the GDP per capita 2005 and was nearly US\$25 800. (Olszewski, 2007; Phang & Toh, 2004)

Different to most other countries, the growth of the vehicle fleet was less than the growth of GDP, see Figure 8. The number of cars per 1000 inhabitants was 63 in 1975 (Seik, 1997) and still below 100 in 2007 (Land Transport Singapore, 2008, URL) which is far below any other country with similar GDP per capita. Looking at it another way, the roads counts for 12% of the country's space and the number of vehicles per mile of road 1992 were 319 which is substantially higher than the UK (100), Japan (69) and the United States (44) for the same year. The importance of scarce land use and tackling congestion with demand measures (rather than supply measures) was therefore recognized decades ago, as peak hour speeds decreased below 19 km/h in the city (Phang & Toh, 1997). The introduction of the Area Licensing Scheme (ALS) 1975 was one of several measures to tackle congestion. Another approach has been to keep the vehicle fleet at controllable levels with measures such as vehicle quotas and high import taxes. (Olszewski, 2007)

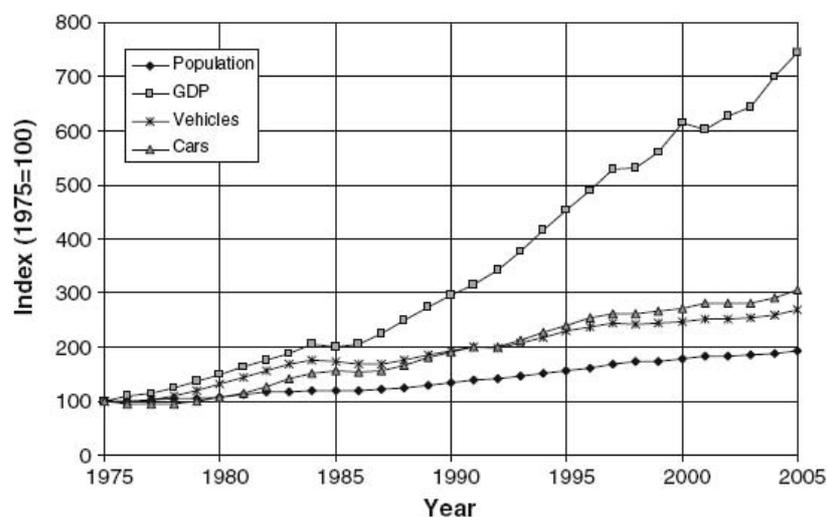


Figure 8– Growth in Singapore's population, real GDP and vehicle population, 1975-2005. (Olszewski, 2007, Figure 1, p.323)

#### 4.2.1 Facts about the Scheme

Singapore introduced the first urban road pricing scheme in 1975 known as the Area Licensing Scheme (ALS). The scheme lasted until 1998 when Electronic Road Pricing (ERP) was introduced. The name ALS might cause confusion as it worked as a single cordon scheme until 1998. (Small & Ibanez, 1998) The 23 year old scheme has gone through four phases under its lifetime:

1975: Manual tolling, 7.30am-10.15am, inbound traffic.

1989: Manual tolling, 7.30am-10.15, inbound traffic and 4.30pm-6.30pm, (in and outbound traffic)

1994: Manual tolling, Weekday Permits (7.30am-6.30pm & 10.15am-4.30pm)

1998: Electronic Road Pricing,

The first scheme was introduced in June 1975 with 22 manually tolled entry points and human monitors surrounding an area of 6 km<sup>2</sup> (Toh, 1992) called the Restricted Zone (RZ) where Singapore's central business district is located. All entering vehicles were required to purchase an entering license and display it in the window shield. The ticket was prepaid and could be purchased at stores for S\$ 3.00 a day or S\$60.00 a month. The charge for company cars was the double as these were tax deductible (Phang & Toh, 1997). Vehicles such as public transport, military vehicles, goods transport, motorcycles and cars with more than three passengers were all exempted the license fee. The fee for entering the RZ was for inbound traffic only during morning peak hours (7.30am-9.30am) Mondays to Saturdays. (Phang & Toh, 2004)

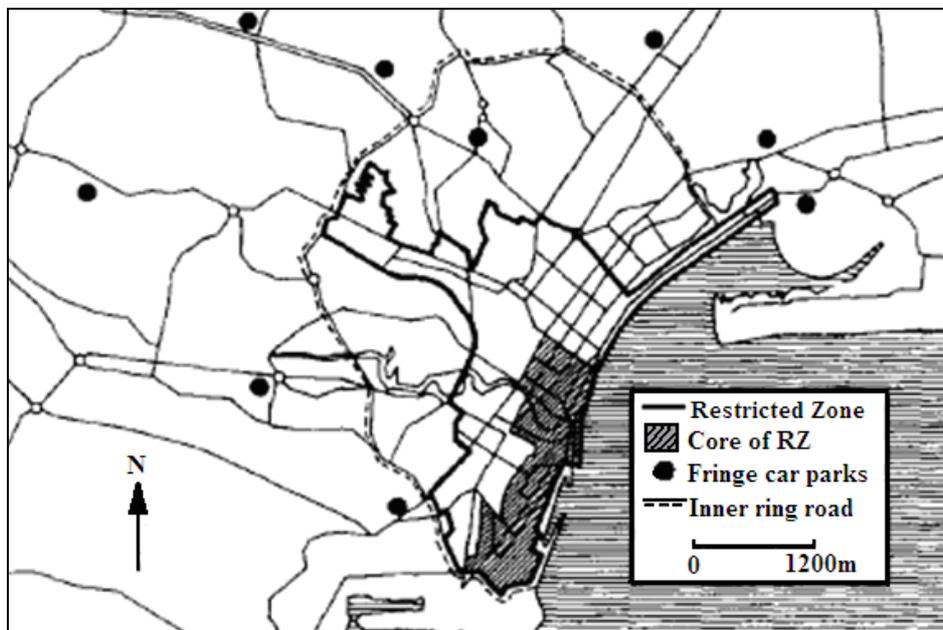


Figure 9 – Map Showing the Restricted Zone (RZ) For more detailed map, (Seik, 1997, p.4, Figure 1)

Parking fees within the restricted zone were raised with 100% and a Park-and-Ride scheme was implemented consisting of 15,000 parking spaces around the Restricted Zone, where commuters could park their cars and take the bus to the city centre. (Phang & Toh, 2004) Bus services was increased by 33% (FHWA, 2008 (URL)).

The goal with the Area Licensing Scheme was to reduce private cars and taxis into the Central Business District (CBD) which was one of most congested areas in the city with an average speed of 19 km/h during peak hours in the beginning of 1975. The target was to reduce traffic volumes with 25-30% during the morning peak hours. It was hoped that this would have a “mirror effect”, resulting in a similar reduction in the evening peak hours.

There is little said about the redistribution of the revenue collected from the scheme. Jones (1998) says that the ALS was primarily introduced to reduce traffic levels and there was little discussion about how the revenues would be spent. Hau (1992) states that “the government is using the area licensing scheme as a traffic management device, rather than a revenue generator.” (Hau, 1992 *cited in* Button, 1998, p. 33)

#### 4.2.2 Effects

After four weeks of operation the traffic flow was reduced by 45.3% by far exceeding the original target of 25-30%. Cars counted for nearly the whole reduction and reduced by 76.2 %.

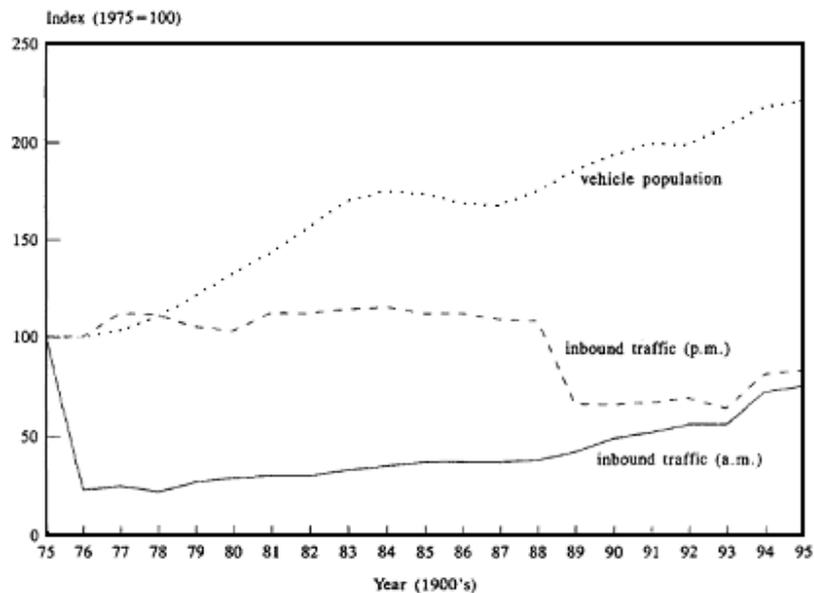
Time	Motor Cars		Other Vehicles		Total	
	March 1975 (Before ALS)	June 1975 (After ALS)	March 1975 (Before ALS)	June 1975 (After ALS)	March 1975 (Before ALS)	June 1975 (After ALS)
7:00 a.m. to 7:30 a.m. (Before Restricted Hours)	5,384	6,565 (+21.9%)	4,146	5,011 (+13.5%)	9,800	11,576 (+18.1%)
7:30 a.m. to 9:30 a.m. (Restricted Hours)	32,421	7,727 (-76.2%)	22,892	22,545 (-1.5%)	55,313	30,272 (-45.3%)
9:30 a.m. to 10:00 a.m. (After Restricted Hours)	7,059	7,479 (+5.9%)	5,716	7,561 (+32.3%)	12,775	15,040 (+17.7%)

**Table 1** – Traffic reduction in July 1977, the initial scheme with operating hours 7.30am-9.30am. (Phang & Toh, 2004, Table 1, p.18)

One of the side effects during this month, as can be seen in Table 1, was that traffic increased half an hour before and after the restricted hours. To cope with this the original restraint hours were therefore extended to 10.15am on August 1. (Phang & Toh, 2004) This resulted in a similar traffic reduction, but the increase half an hour before was only 5% and the half an hour after was 10 percent below the levels in 1975. (Seik, 1997) This structure was kept until 1989 with the exception of increased charges due to inflation and higher consumer income and adjusting the charged zone to the growing CBD area. (Seik, 1997)

Traffic data for the period September - October 1975 showed that the total traffic reduction was 44% (similar to the reduction in July). Buses and carpools went up from 41% to 62% together (Watson & Holland, 1978 cited in Small & Ibanez, 1998, p.216). However, the strong increase of carpooling also created a situation with drivers picking up bus passengers (Santos, 2005). This, in its turn led to a smaller use of park-and-ride facilities than expected. The buses in use for the park-and-ride purpose were eventually used in other areas and the parking facilities transformed to house areas. (Button, 1993)

Average speeds within the restricted zone rose by 20% (FHWA, 2008 (URL)) However, the travel times for solo drivers, carpools and buses all increased during the first months of the scheme indicating that the time savings within the zone were offset by increased congestion outside the zone. Travel times most likely decreased with subsequent road improvements but there is no data supporting this. (Small, Ibanez, 1998)



**Figure 10** – Changes in volume of traffic during the morning and evening peak hours. As can be seen for the first year of operation, only the inbound traffic in morning hours reduced while the evening traffic remained at the same levels. However, traffic reduced significantly in 1989 when the scheme was changed to include evening hours as well. (Seik, 1997, p.161)

By levying a fee for morning hours only, it was assumed that the same effect on traffic would also occur in the evening hours. As shown in Figure 10, the hoped mirror effect in 1975 never occurred. People working on the far side of the restricted area avoided the zone in the morning hours but went through it in the afternoon. (Small, Ibanez, 1998) Others carpoled in the morning but were picked up by family members in the evening that adjusted their own routines by e.g. shopping in the city at the same time (Button, 1993). Another side effect was the increase of trucks by 124% during the first months in the restricted zone. (Small, Ibanez, 1998)

Phang and Toh (2004) add the following key results from the introduction of the Area Licensing Scheme: First, the tolls were too high leading to underutilized roads in the CBD and a traffic level under the optimal flow. Secondly, the problem with traffic congestion had been moved in place and time, thus, not been eliminated.

#### **4.2.3 Traffic outside the zone**

The response in traffic for the first year of ALS, was a 10% increase in speeds on inbound roads to the zone, while the speeds on the ring road reduced by 20%. (FHWA, 2008(URL)) The average travel times for bus riders and car commuters increased. (Small, Ibanez, 1998)

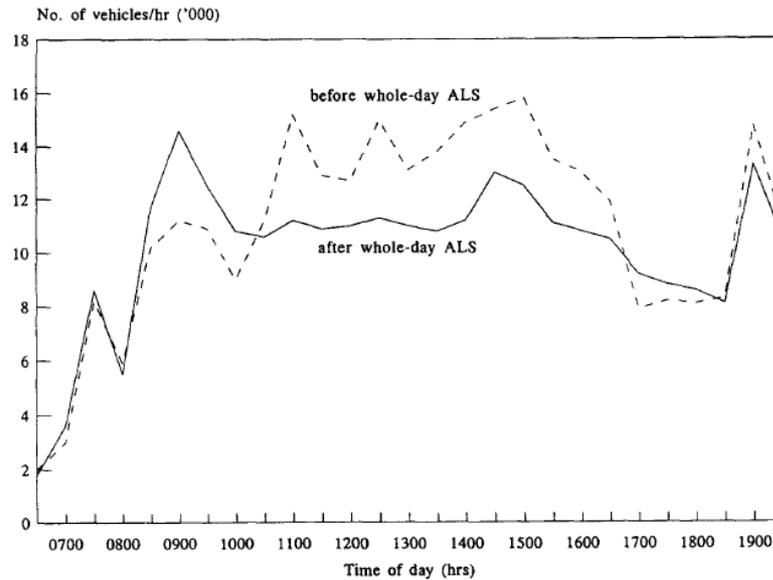
#### **4.2.4 Area Licensing Scheme 1976-1998**

As the economy grew rapidly the vehicle fleet nearly doubled between 1975 and 1989. For the same years the number of vehicles entering the restricted zone rose from 41 500 in 1975 to 51 000 for the same years which was a move towards optimality. (Seik, 1997: Pang & Toh, 2004)

However, the traffic reduced again in June 1989 when the scheme was changed in order to get around the problems with increased goods vehicles and the lacking “mirror effect” in the afternoon. The first problem was addressed by removing a number of exemptions, leaving military vehicles, emergency vehicles and scheduled buses as the only vehicles free from charge. To address the mirror effect problem, a toll in the afternoon between 4.30pm to 7.30 pm (later shortened to 6.30pm) was introduced. The toll that currently was S\$5.00 was lowered to S\$3.00. (Phang & Toh, 2004) The toll was set for both inbound and outbound traffic. The effect was that inbound traffic was shifted to after peak hours, mainly for recreation and shopping purposes. (Seik, 1997) These measures together reduced the traffic that in November was 44% lower in the afternoon peak time, while the traffic in the morning reduced by 14% to almost the same levels as in October 1975. The government announced that the traffic speed had increased by 20%. (Phang & Toh, 2004)

In May 1991 the average speed during peak hours was 35 km/h, compared to 10 New York and 18 in London, indicating that roads were “emptied out”. (Phang & Toh, 2004, p.3)

As shown in Figure 11 the traffic flow in the early 1990s was higher in the inter peak hours than in the peak hours. To smooth out the flow a new two tier system was introduced, including a whole day and a cheaper part day license. The prior was valid 7.30am-6.30pm and the part time license 10.15am-4.30pm. (Phang & Toh, 2004)



**Figure 11** – Inbound traffic during a day, before and after the commencement of “Whole day” and “Part day” licenses in 1994. (Seik, 1997, figure 6, p.162)

As shown in Figure 11, the morning traffic increased (from 49 000 to 60 000), the afternoon traffic decreased (from 168 000 to 143 000) and the evening peak traffic increased (from 28 000 to 34 000 vehicles). (Phang & Toh, 2004)

Increasing traffic and congestion on road bypassing the restricted zone led to the introduction of road pricing on the East Coast Parkway in June 1995 (Seik, 1997). As well, this was partly done to familiarize the Singaporeans with passage tolls i.e. tolls charging per passage instead of a daily charge. Vehicles driving on the road between 7:30am and 8:30am were subject to a charge. The effect on the RLS was a reduction with 42% and an average speed increase from 29 km/h to 64 km/h. (Phang & Toh, 2004)

#### 4.2.5 Electronic Road Pricing, 1998-

Road pricing was planned for other certain expressways. However, In 1998 Singapore introduced Electronic Road Pricing (ERP), which both replaced the Area Licensing Scheme and road pricing outside the area. The ERP gave a more flexible system that was more able to adapt costs to actual marginal social costs depending on time and traffic levels. As well, the charge could be levied according to the passenger car unit of a vehicle (Santos & Fraser, 2006). As well, charges could be levied per passage without disturbing the traffic flow, and facilitated the enforcement of the 16 different licenses existed at the time. (Phang & Toh, 2004) Generally the central roads were levied 7.30am-7.00pm and expressways and other roads in the morning peak (7.30am -9.30am). (Santos & Fraser, 2006)

The objective of the ERP was to maintain an average speed of 45-65 km/h on expressways and 20-30 km/h on main roads (Santos, 2005). The initial effect of the ERP scheme was a traffic reduction

of 10-15 percent mainly caused by the reduction of multiple trips as a result of charges being levied per passage. In 1999 the ERP was extended to other locations and in 2003 there were 45 gantries covering the restricted zone.

Another improvement was the possibility of smoothing out the charges between the peak and none peak periods. For example, some roads that used to change from S\$2.00 to S\$3.00 added an interval of 5-10 minutes charging S\$2.50. This, to avoid that the motorists either speeded up or slowed down in order to avoid high price changes. (Phang & Toh, 2004)

In 2007 and 2008 the ERP was expanded with 16 new gantries. Of those, 5 were activated inside the restricted zone dividing the area into two halves. (Singapore LTA, 2008 (URL))

#### 4.2.6 Public Transport

Public Transport travel speeds within the zone increased by 20% for all traffic (including buses) but the average travel times rose as an effect of increased congestion outside the zone (Small & Ibanez). However, FHWA (2008 (URL)) claims that these probably benefited from improvements and expansions in public transport over time. See chapter 3.5.6 “Equity Impact”

Cars entering the restricted zone have decreased significantly in Singapore while public transport has increased. The share for cars commuting to the restricted zone decreased from 56% to 46% in 1975 and has been stable on 23% since 1983. During the same years the share for public transport increased from 33% to 49% in morning hours. (FHWA, 2008 (URL))

**Modal share Car & Public Transport entering RZ**

	1975	1976	1983
<b>Car</b>	56%	46%	23%
<b>Public Transport</b>	33%	46%	69%

**Table 2 – Modal share for morning hours 1975-1983. (Adapted from FHWA, 2008 (URL))**

#### 4.2.7 Equity Impact

According to FHWA (2008) the shift from car to public transport was overall the same for low, medium and high income travelers in the peak hours whose modal share increased by 25%, 34% and 28%. There was no evidence that the travel times increased for any particular income group. Furthermore, FHWA (2008) claims that middle income travelers felt adversely affected by the ALS. Related to this, Mohring (1999) argues that the taxes on vehicles in Singapore are and were already the highest in 1975 and only the wealthiest Singaporeans could afford a private car.

Attitudinal surveys were carried out after the implementation of the Area Licensing Scheme. Pedestrians, residents outside the restricted zone and taxis were neutral or negative, while residents

within the zone, bus passengers and cyclists perceived themselves as better off. (FHWA, 2008, (URL))

Groups (Transit riders, motorcyclists, car pools and pedestrians) likely to have benefited from the ALS represented 52% percent of the travelers to the RZ in 1975 before the commencement of the ALS. (FHWA, 2008 (URL))

#### **4.2.8 Business impact**

Surveys were carried out regarding possible economic impact in the RZ. There was no evidence that congestion pricing affected rents or office development negatively. Other factors appear to have been of higher importance. The ALS had a minor impact on retail sales in 1976 and when the charge was extended for evening peak, some retail shops reported sharp decreases in trade. Moreover, there was no reduction in labor availability and there was no sign of changes in land use for business and the “business community responded positively to the ALS”. (FHWA, 2008 (URL))

#### **4.2.9 Implementation process and public opinion**

There is little said in the literature regarding implementation process and public opinion. However, several authors point out the high acceptability among the people in Singapore regarding demand measures. Bull (2003) stresses that Singapore is a special case in terms of being a small island nation with a one level government providing for an efficient traffic management system (Seik, 1997). In addition, the island’s government (which has been reelected at every election since 1959) has had extensive power and the citizens have a high acceptance of regulations not only regarding road pricing. According to the Federal Highway administration (2008, URL) the government could have implemented congestion pricing in 1975 without consulting the public. However, a yearlong assessment and consultation was carried out with adjustments according to the public response. In addition, congestion pricing has been packaged with other measures such as public transport improvements and other demand measures in order to enhance the acceptability. Overall, the public reacted favorably to the pricing scheme and the other measures implemented. (FHWA, 2008 (URL))

### 4.3 London

In 2000, the Transport Act was passed in the United Kingdom which enabled local Authorities in England and Wales to introduce congestion pricing, in order to tackle congestion. Durham was the first city in 2002 but is less known due to the small scale of the scheme. London was the second city in 2003 and is likely the most well known example, with extensive information and follow ups by the local transport authority, *Transport for London*.

#### 4.3.1 Facts about the city

London had in 2006 a population of 7.9 million and a density of 4.761. (Wikipedia, 2008c) The city has suffered from congestion for long and congestion pricing was recommended as suitable measure decades before the implementation in 2003. (Litman, 2006). As shown in Table 3, average speeds in central London had seen a negative trend since 1986 and were down at 14km/h in 2002.

Average Speeds in Central Zone					
1986	1990	1994	1997	2000	2002
17.2	15.6	16.3	14.9	14.1	14.2

Table 3 – Average "all day" speeds for selected years in the central zone in London. Measured in June/July (TfL, 2003, Table, 3.4, p.53)

The street network in the central of London had hardly been expanded since the medieval ages and its limited capacity resulted in severe congestion. As relatively good travel alternatives were provided, the central area was suitable for congestion pricing. (Litman, 2006) According to Transport for London (2008, (URL)) Londoners spent 50% of their travel time queuing in weekday mornings and the costs due to congestion was estimated to be £2-£4 million a week.

As shown in Figure 12, of the people entering central London in morning hours in 2001 84% were on public transport and 12% used cars, generating a PT/Car relationship of of 87.5/12.5. If only counting buses and cars the share was approximately 33/67. (TfL, 2003) The number of cars per 1000 people in London was 330. (Singapore Land Transport Authority, 2008 (URL))

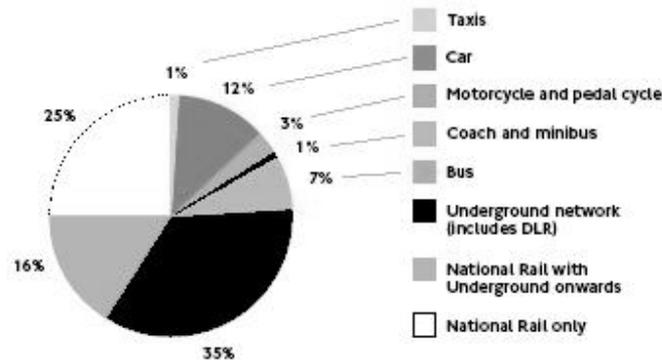


Figure 12 – Mode Shares for People entering central London in a typical weekday, 07.00am-10.00am, 2001. (TfL, 2003, Figure 6, p.130)

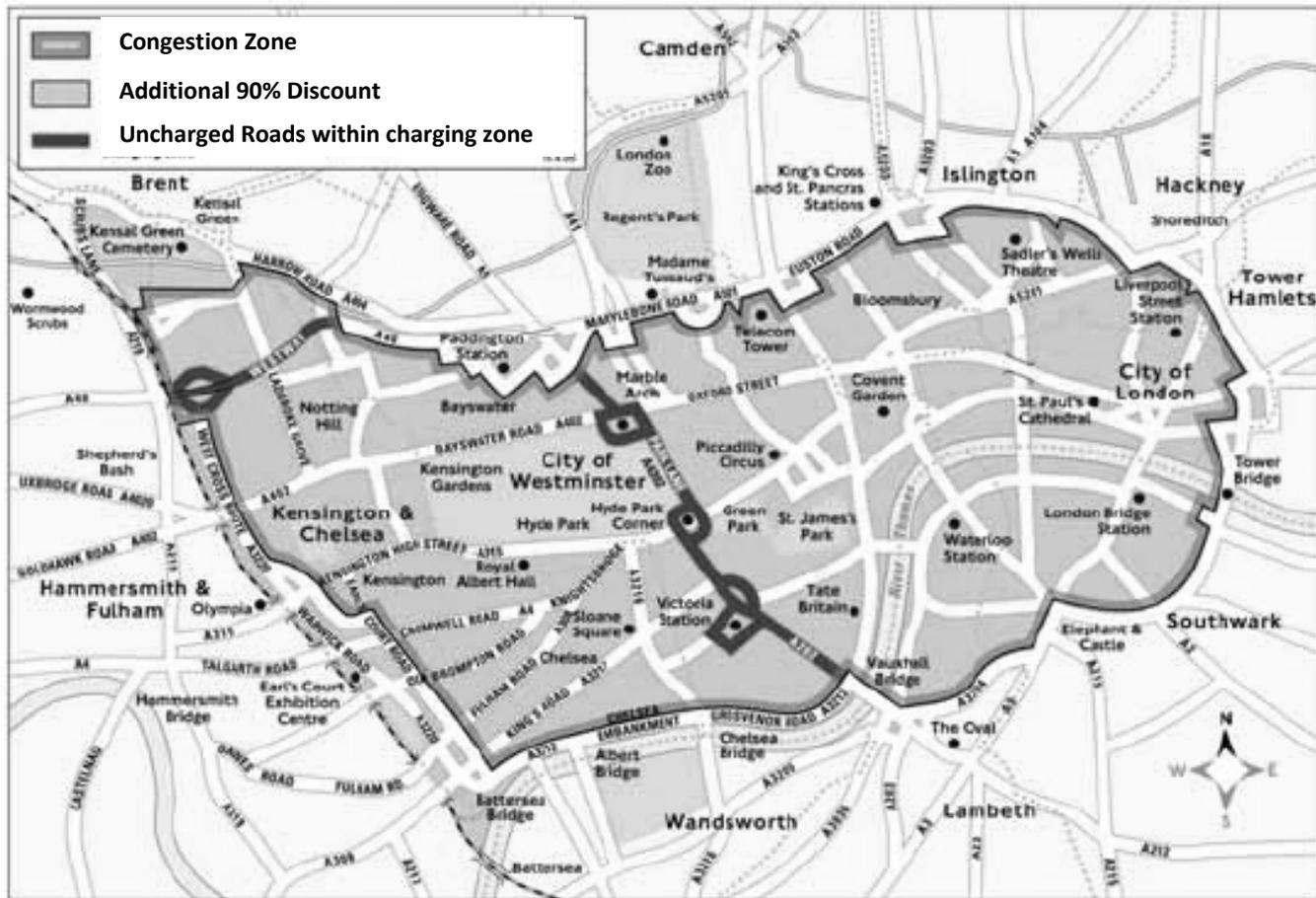
#### 4.3.2 Facts about the Scheme

The London congestion charge scheme (LSSC) was introduced in February 2003. The primary objective of the scheme was to reduce traffic congestion inside and around the congestion zone. It was also expected to contribute to four of the Mayor’s ten priorities in his transport strategy: “to reduce congestion, to make radical improvements in bus services, to improve journey time reliability for car users, and to make the distribution of goods and services more reliable, sustainable and efficient” (TfL, 2004b, p.7 *quoted in Santos and Fraser, 2006, p.279*)

Vehicles entering or driving within the area Monday – Friday, 7.00 – 18.30 (18.00 after 2007) were subject to a congestion charge. Certain classes of vehicles were exempt of charges such as public transport, taxis, emergency vehicles, disabled persons, motorcycles and alternative fuel vehicles (e.g. electric cars). Residents within the charged zone received a 90% reduction of the charged price. Even though alternative fuel vehicles get a 100% discount it is more an environmental benefit rather than based on reducing environmental pollution. (Santos & Fraser, 2006)

London has gone through various phases with a change of price and an extension of the size of the charged zone.

- 2003, Feb 17: £5.00, charged area, 22 km<sup>2</sup> (London CBD and major part of Westminster.
- 2005, July 5: Charge: £8.00
- 2007, Feb 17, Expansion of the charging zone, see Appendix C



**Figure 13-** Map of Charging Zone 2008, the zone was expanded west of A202 in 2007 (The road in the middle, marked in black). As can be seen in figure, there are two free routes crossing the zone (A202 & A40) (TfL, 2007)

The original charging zone in central London was 22 km<sup>2</sup> or 1.3% of London's total area and consists of the central business district and the major part of Westminster, surrounded by major roads commonly called the Inner Ring Road. There were 174 entries and exits from the levied area (Santos & Fraser, 2006). A flat charge of £5.00 was levied 7.00am – 6.30pm, Monday – Friday (Downs, 2004). As London experienced high congestion throughout the day, a variable toll was of less importance. The enforcement was carried out by 203 cameras in the entrances and exits to the charged zone as well inside it. (Santos, 2005)

The capital costs for the LCCS were about £200 of which most were provided by the central government. (Santos & Fraser, 2006) According to the Transportation act 2000 the net revenues from the scheme had to be spent on improving transport for the first 10 years of scheme operation. (TfL, 2007b) For the first five years, 80% were allocated to bus improvements, 13-15% to road safety and road improvements. 6% of the net revenues in 2003 were allocated for walking and cycling and were 1-3% for the subsequent years. (TfL, 2004-2008)

### 4.3.3 Effects

Transport for London (2003) predicted a reduction for all vehicles between 10% and 15% and a reduction in congestion with 20% -30%. In Table 4 can be seen that the actual traffic reduction was 14% and TfL (2004) reports that the reduction in congestion within the charging zone was 30%. The number of cars and minicabs reduced by 36% and private cars in peak hour reduced by 20% (Litman, 2006). Measured in vehicle kilometres travelled (*vk<sub>t</sub>*), traffic was reduced by 12% within the charging zone for, the years 2002 and 2003. (TfL, 2006)

Table 3.1 Key year-on-year changes to traffic entering the central London charging zone during charging hours, 07:00-18:00.

	2003 vs 2002	2004 vs 2003	2005 vs 2004	2006 vs 2005	2007 vs 2006	2007 vs 2002
All vehicles	-14%	0%	-2%	0%	0%	-16%
Four or more wheels	-18%	-1%	-2%	-1%	0%	-21%
Potentially chargeable	-27%	-1%	-3%	0%	1%	-29%
- Cars and minicabs	-33%	-1%	-3%	-1%	0%	-36%
- Vans	-11%	-1%	-4%	2%	1%	-13%
- Lorries and other	-10%	-5%	-4%	6%	9%	-5%
Non chargeable	17%	1%	-1%	-1%	-1%	15%
- Licensed taxis	17%	-1%	1%	-3%	-5%	7%
- Buses and coaches	23%	8%	-4%	-3%	5%	31%
- Powered two-wheelers	13%	-2%	-9%	0%	-3%	-3%
- Pedal cycles	20%	8%	7%	7%	12%	66%

Table 4 – Changes in traffic entering the original charging zone between 2000 and 2007. (TfL, 2007a, p.41)

As there were tendencies of increasing traffic, the charge was raised to £8 in July, 2005 (Bang & Moran, 2006). Traffic for London predicted a reduction for vehicles with four wheels between 2% and 6% (Santos & Fraser, 2006). The results may look poor looking at Table 4. However, the year is an average for the whole year before and after the new charge. Secondly, another two findings make these results complicated to interpret: The charge was levied only four days before the Bombings of London's central parts causing a short term drop in underground travel affecting an increase of other modes of travel. Secondly, the autumn of 2005 was characterized by good weather which probably affected the preferred mode of transport. (TfL, 2005)

Figure 3.2 Traffic entering the central London charging zone by time of day. Annualised weekdays for 2002 (pre charging), and 2003 to 2007 (post charging), all vehicles.

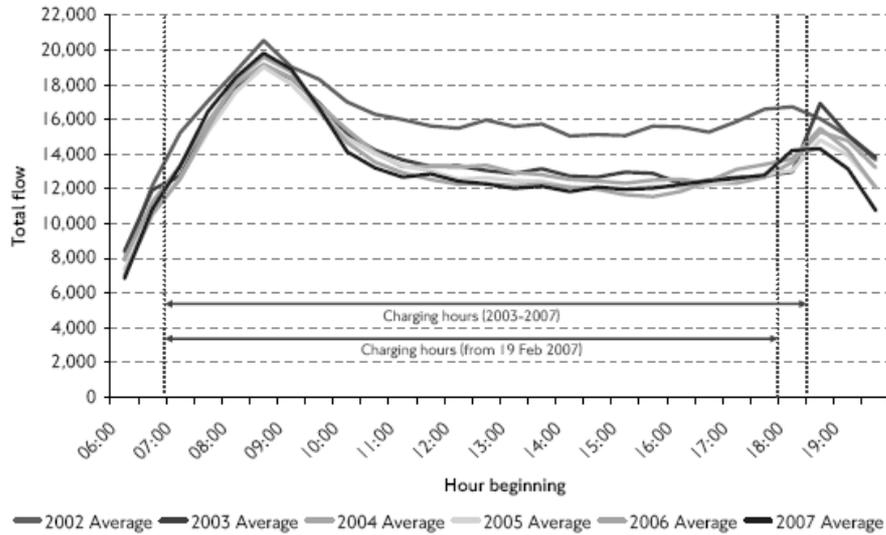


Figure 14- Traffic flow throughout the years 2003-2007 for the original congestion zone (TfL, 2008, Figure 3.2, p.42)

As shown in Figure 14, the traffic flow clearly decreased when compared to the first year. The charge also created a clearer difference in traffic flow in peak and inter-peak periods. In the first half an hour after scheme operation, the traffic flow increased to levels higher than in 2002. However, this flow decreased in the subsequent years. The smallest reduction between pre and post charging years can be seen in the morning peak. (TfL, 2007)

#### 4.3.4 Congestion

Congestion in London is defined as the time for a certain trip exceeding the time spent under free-flow conditions. The average free-flow time in 2002 was 1.9 min/km and average travel time 4.2min/km. Thus, the average excess time was 2.3min/km in 2002 when travelling through the original congestion zone.

<u>Average Speeds for charging hours (km/h)</u>						
2002	2003	2004	2005	2006	2007	2008
14	17	17	16	15	14	14
<u>Mean Excess travel rate (min/km)</u>						
2002	2003	2004	2005	2006	2007	2008
2.3	1.6	1.6	1.8	2.1	2.3	2.3
<u>Congestion relatively to 2002</u>						
2002	2003	2004	2005	2006	2007	2008
0	-30%	-30%	-22%	-8%	0%	0%

**Table 5** – Average speeds and average congestion measured inside the charging zone. Note, data for 2008 are only January-April. (Adapted from TfL, 2007a, 2008, p.57)

As can be seen in Table 5, congestion reduced by 30% and average speeds increased to 17 km/h (21%) for the first year. In the morning peak hours (7.00-10.00am) the increase was 37% (Litman, 2003 cited in Downs, 2004). Congestion was generally reduced by the fact that cars spent less time in stationary or slowly moving queues (rather than increased driving speeds), thus, generating better average speeds (TfL, 2004).

For the years after 2004, congestion and average speeds saw a negative trend and were in 2008 back at the same levels, as in 2002. (TfL, 2007a, 2008) Transport for London (2008) relates this trend to road works and reallocation of road space to busses, cyclists and pedestrians.

### 4.3.5 Traffic on the inner ring road and outside the charging zone

The traffic on peripheral roads was predicted to rise and traffic management was made to meet the new traffic demand. The inner ring road surrounding the charging zone was improved by extending the green light time between 1-2 seconds. Thus, even though the vehicles kilometres driven increased by 4%, congestion did not rise and remained, overall, at the same levels for the subsequent years. (Santos, 2005; TfL, 2008) When the charging zone was extended in 2007 the western “side” of the inner ring road was kept as a free passage route. As the charging time was reduced half an hour this obviously changed the vehicle kilometres driven in 2007. However, compared to the charging hours 7.00am – 18.00pm in 2006 there is no increase for 2007. (TfL, 2007a & 2008)

Traffic on roads approaching the charging zone decreased with 5% and congestion with 20% for the first year and have remained at the same levels for the following years. (TfL, 2004, 2008)

Measures were carried out on roads outside the zone and there were no evidence of increased traffic in 2003. (TfL, 2004)

### 4.3.6 Public Transport

Transport for London met the expected increased demand for travelling with bus with bigger buses, increased frequency and new routes. The total numbers of buses entering the zone during charging hours increased by 23% for the first year and had increased with another 8 percentage points in 2007.

In the morning peak (7.00am-10.00am) in 2003, the increase of buses was 23% while the number of passengers was 38%, resulting in an average of 4 more passengers (12%) per bus (Santos & Fraser, 2007). TfL(2004) estimated that half of the increased patronage was related to the congestion charge. The number of trips with the metro remained at the same levels as in 2002 (Santos & Fraser, 2006)

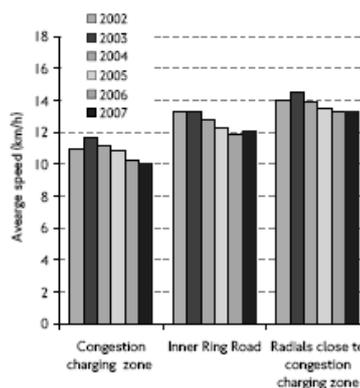


Figure 15 – Average bus speeds in the original charging zone, on the inner ring road and radials close to the congestion zone. (Adapted from TfL, 2008, p.92)

As can be seen in Figure 15, average bus speeds in the original congestion zone increased in 2003 but has decreased to levels lower than pre charging levels for the subsequent years. Similarly on the ring road and orbital roads close to the zone average speeds either improved or were the same in 2003 but have decreased in the years after that. In Table 4 can be seen that the number of entering buses in 2007 was approximately the same as in 2004. There is no data available about the number of daily passengers entering the zone for the same years. However, data for the morning peak (7.00am-10am) shows that the number of passengers has been relatively stable for the same years. (TfL, 2008)

A way of measuring the bus reliability is to measure how much bus journeys exceed their scheduled time, called excessive waiting time. In Table 6 can be seen that the excessive time dropped 30% for the first year and decreased another 18% in 2004. However, for the last years this time has increased again. The trend outside the zone has overall been the same as inside the charging zone. (TfL, 2008)

**Bus excessive time relatively to 2002**

2003	2004	2005	2006	2007	2007/2002
-30%	-18%	-4%	2%	8%	-40%

**Table 6 – Excessive waiting time relatively to 2002, for busses in the original charging zone. (TfL, 2006-2008)**

The perceived changes among residents in London were assessed in an attitude survey in 2003. The answers, presented in Table 7 below, were either "better" or "worse" (people answering "no change" or "don't know" are not presented) In all areas people perceived that the availability of transport was better. The reliability of public transport was also perceived better among the respondents in inner London.

**Perceived Changes to Local Area by residents in different areas of London**

	Charging Zone		Inner London		Outer London	
	Better	Worse	Better	Worse	Better	Worse
<b>Availability of Transport</b>	47	8	39	9	16	10
<b>Reliability of PT</b>	38	12	30	12	12	20

**Table 7 – Perceived Changes to Local areas by its residents inside the charging zone, inner London and outer London. (Adapted from TfL, 2004, Figures 5.8, p.68, figure 5.10, p.70, figure 5.12, p.70)**

The customer satisfaction with bus services within and outside the congestion zone was assessed in 2002 and 2003 in terms of time waited to catch the bus, journey time and level of time waiting for the bus. All areas (but crowding, within the zone) scored higher in 2003, though the changes were relatively small. (TfL, 2004)

### 4.3.7 Modal Swap

Of the 65 000 to 70 000 cars that no more entered the zone an average day in 2003, 50-60% transferred to public transport, 20-30% diverted around the charging zone and 15-25% adapted in other ways such as walking, cycling, motorbike, car share, travel outside charging hours or change of destination. (TfL, 2004)

According to Litman (2003 *cited in* Downs, 2004) before the implementation of the congestion charge in Feb. 2003, 1.1 million people entered the charged area in the morning peak (7.00am-10.00am) of which 84% were on public transport and 12% on private vehicles (about 100 000). After the implementation the number of private vehicles reduced by 20 000 a day (in peak hour) resulting in a modal share of about 10% for cars. (Downs, 2004; Litman 2006) Calculating the car/PT ratios in the morning peak cars reduced from 12% to 10% equal to a reduction by 17%. Assuming that about 50% swapped to public transport (and that public transport did not change in patronage apart from new passengers from cars) the new mode share pt/car is estimated to have been 89/11 (Author's Remark).

### 4.3.8 Residents

Respondents living within the original congestion zone were in 2003 asked if they perceived themselves being better off in terms of congestion, pollution and noise compared to 2002. As can be seen in Table 8, in all three categories, there were more responding "better" than "worse". Other respondents either "didn't know" or could not see any change.

**Perceived Changes to Local Area by residents in the Charging zone**

	Better	Worse
<b>Congestion</b>	55	10
<b>Pollution</b>	33	8
<b>Noise</b>	36	8

**Table 8** – Perceived Changes to residents inside the charging zone. (Adapted from TfL, 2004, Figures 5.8, p.68, figure 5.10, p.70, figure 5.12, p.70)

### 4.3.9 Other vehicles

Powered two wheelers increased by 13% for the first year but reduced in the subsequent years back to pre-charging levels.

Cycling saw an increase of 20% for the first year and continued to grow in the subsequent years in line with the general growth in London. The number of entering cyclist in the charging zone was 66% higher in 2007 than in 2002. (TfL, 2006, 2008; Homepage of government of London, 2008)

### 4.3.10 Economic Impact

According to TfL (2008) no clear impact can be seen on the businesses in central London. For the years 2003-2008, business within the charging zone followed general economic trends for London overall. The property market appeared not to have been adversely affected by the charging scheme.

### 4.3.11 Implementation process and public opinion

There was never a public referendum regarding the implementation of the congestion charge. Instead, congestion pricing was part of the Mayor’s manifesto for the election in 2000. However, the public was consulted regarding several issues such as the level of charge, time of charge and the size of the scheme and the decisions were finally made on political decision rather than economical decisions. This resulted in a £5.00 charge (instead of £10.00 that was considered earlier) as well as abandoning a proposal of charging heavy goods vehicles three times the normal charge. The charging time was firstly proposed to end at 7.00pm but was changed to 6.30pm as it was assumed to reduce the number of people going to the theatre at night. (Santos & Fraser, 2006)

However, the charge was increased in 2005 to £8.00 despite the opposition of the respondents of a public consultation. Santos and Fraser (2006) claim that people to be worse off of a congestion scheme are more likely to participate in public consultations. For example, in a public consultation in 2005, both residents living within the proposed area and in the original charged zone opposed the proposal of extending the charging zone westwards even though both areas were likely to benefit from the scheme. In the proposed area residents would experience time savings. Besides, those who travel to the original congestion zone would be granted a 90% discount. Similarly residents living in the original zone would benefit from the time saving if they travelled to the proposed zone. Despite these facts, 72% of the respondents in the proposed area and 66% in the original area opposed the scheme.

To compare these findings Traffic for London commissioned an attitudinal survey in order to see how representative the consultation findings were. Table 9, shows the different results when Londoners were asked if it was important to tackle congestion in the proposed zone.

	Public Consultation		AttitudeSurvey
	Business	Gen Public	All
<b>Unimportant</b>	52%	47%	16%
<b>Important</b>	34%	41%	62%

**Table 9 – Difference between Public Consultation (PC) and Attitudinal Survey (AS) . (Adapted from Santos & Fraser, 2006)**

To assess Londoners attitudes to the congestion scheme, seven surveys were carried out between 2002 and 2003. The three first, were all carried out before the implementation of the congestion

charge. The number of supporters of the scheme was about 40% and was either exceeded by or the same as the percentage opposing the scheme, in each survey, see Table 10. However, for the four surveys after the scheme implementation the supporters were between 48% and 57% exceeding the opponents in all four surveys.

	Before Charging			After Charging			
	2002	2003	2003	2003	2003	2003	2003
	Dec	Jan	Feb	Mar	Apr	Jul	Oct
<b>Support</b>	40	38	39	57	50	59	48
<b>Neither</b>	19	16	18	26	18	15	21
<b>Oppose</b>	40	43	41	27	31	24	28

Table 10 – *Attitudes among Londoners from Dec 02 to Oct 2003. (Adapted from TfL, 2004, Table 5.2, p.76)*

In 2008, the then mayor proposed a new pollution based charge, varying £0-£25 according to the level of CO<sub>2</sub> emissions of an entering vehicle. (London Government, URL, 2008b) The idea was abandoned by the new mayor of London elected in May 2008.

The new mayor decided to carry out a public consultation regarding the new Western Extension zone (Implemented in 2007) in September and October 2008. Of the 28 000 respondents (both business and individuals) 69% supported the removal of the western extension, 19% supported the western extension and 12% supported changing the scheme to improve the way it operated. (The result was 41%, 30% and 15% for the same questions in an attitudinal survey, assessing the opinion among Londoners. (TfL, 2008b)) Based on these results, the new mayor announced his intention to remove the western extension. The removal could be carried out at the earliest in 2010. (TfL, URL, 2008)

## 4.4 Stockholm

Stockholm introduced congestion pricing as a trial in spring 2006 and on permanent basis in fall 2007. Stockholm had an urban population of 1.252 million in 2007 and a density of 3,313 people/km<sup>2</sup>. (Wikipedia, 2008d) The population of Stockholm increased by 250 000 people for the years 1990-2005 equal to an annual growth of 1.2%. (Swedish Road administration, 2008a (URL))

In 2008 the metropolitan area of Stockholm had 370 cars per 1000 inhabitants which is the lowest figure in Sweden and below the average for the country (510). (Homepage of Infotorg, 2008) Data from the Royal institute of Technology in Stockholm (2006) shows that the annual traffic growth has been relatively low or unchanged in the central of Stockholm for the period 1990-2002, despite that the traffic for the Stockholm region increased by 1.7% annually for the same time. The reason was likely that the traffic had reached capacity levels, especially in peak hours. (Bång & Moran, 2006) Road pricing was discussed already in the 1990s as a measure of both reducing traffic and to finance a package of new infrastructure in the city. However, the plan was abandoned a few years later. (Johansson & Mattsson, 1994)

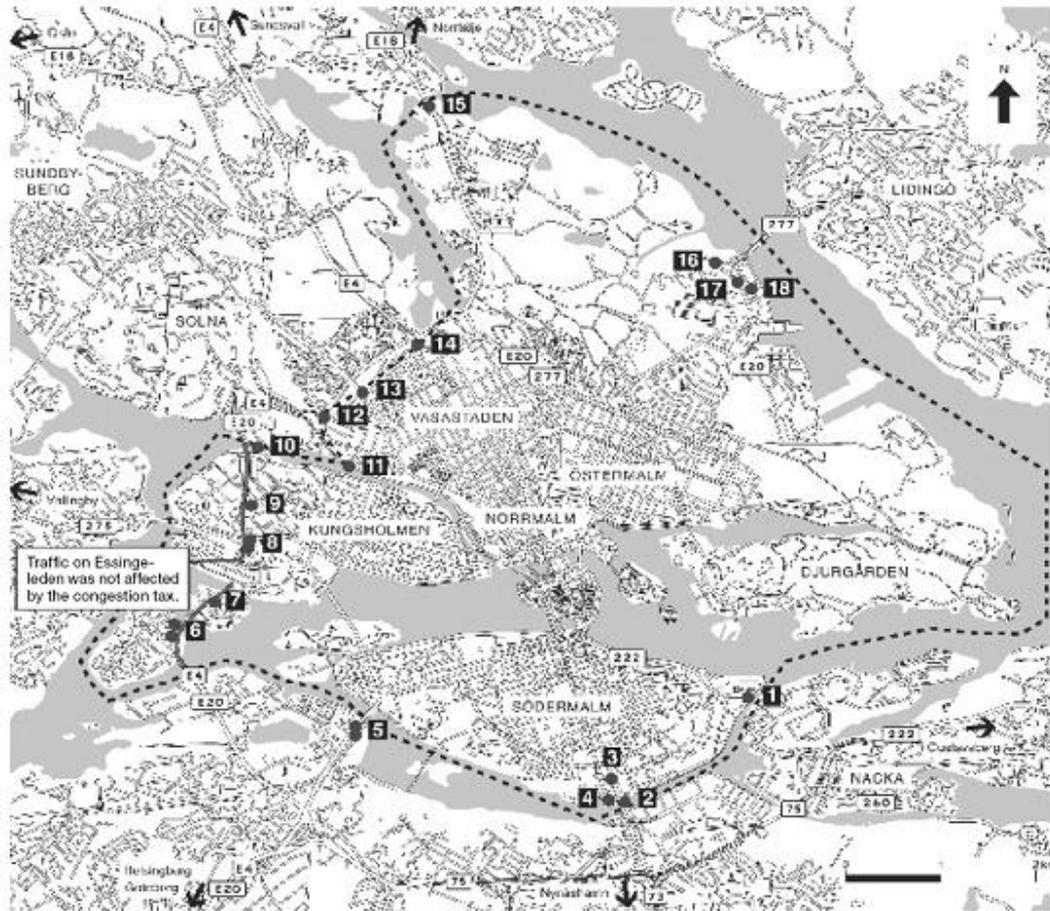
The mode share in 2005 for people commuting into the city in the morning peak (7.00am-9.00am) was 70/30. Kottenhoff and Brundell Freij (2008) describe the Stockholm urban area as public transport friendly and the city had a high quality public transport before the trial in 2006. The public transport system in Stockholm comprises bus, regional trains, trams and metro.

### 4.4.1 Facts about the scheme

The Stockholm Congestion tax was implemented on trial from January 3 to July 31 in 2006 and operating permanently as of 1 July, 2007. Differently to London there was no charged zone in Stockholm but instead a charged cordon surrounding central Stockholm (However, the area inside will still be referred as the “charged area” or “charged zone” in this chapter). This means that vehicles are only charged when crossing the cordon and can still drive within or outside the cordon for free. (Swedish Road Administration, 2008a) The charged area (34 km<sup>2</sup>) was equal to 18% of the city area with 33% of the residents of Stockholm city living inside (22% of the urban population). 60% of all jobs in Stockholm City were inside the charged zone (30% of all jobs in of metropolitan Stockholm). (Stockholm Trial, 2006 (URL))

As shown in Figure 16 the charged area comprised central Stockholm with 18 entry points. Drivers travelling east-west could travel for free through “Södra Länken” (south of the charged area), while those driving north-south could avoid the charge, by going on the European route 4 (Essingeleden) even though it goes through the western part of the levied area. Another exemption was applied for the cars entering from the Island *Lidingö*, as they had to go through the charged zone in order to

access the national road network. These were free from charge if they left the zone within 30 min at any other toll station. (Swedish Road Administration, 2008a)



**Figure 16** – Map of charged zone with the free route “Essingeleden” going through the charged zone (entry points 6-10). The Island “Lidingö” can be seen up in the right corner. The only exit for the people is through the charged cordon. Therefore, those exiting the charged area within 30min are exempted the fee. (Swedish Road Administration, 2008a, p. 6)

All vehicles crossing the border were levied a charge Monday to Friday, 6.30am-6.30pm. There was no charge in July when traffic generally is lower, due to holidays. The charge was 5 to 20 Swedish kronor (approximately €0.5-€20, 2008 exchange rates) depending on the time of day, see Figure 17. The maximum price for a day was limited to 60 kr (€6, 2008 exchange rates).

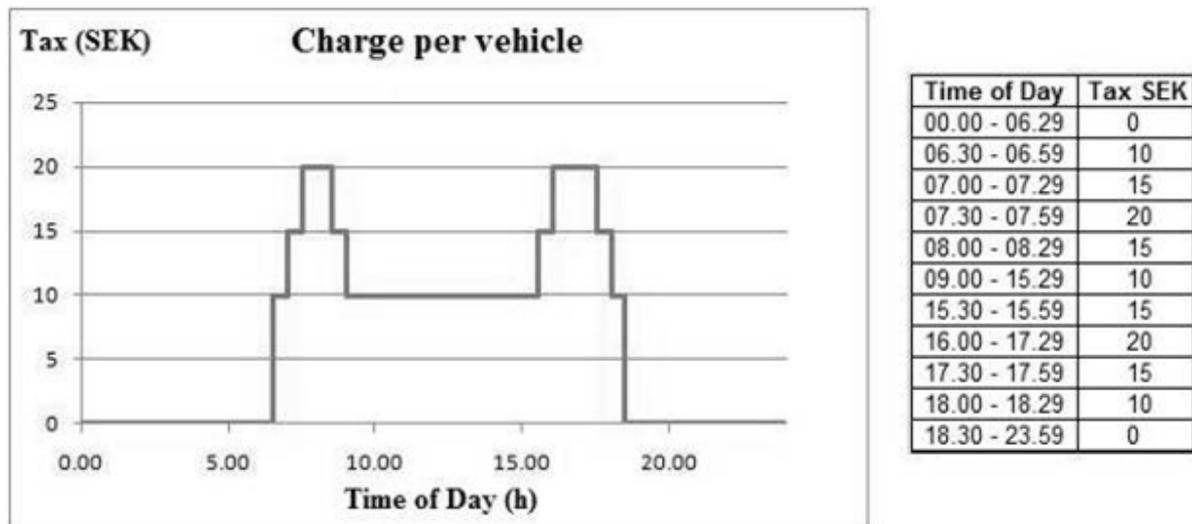


Figure 17 – Time and amount of levied tax on vehicles. (Adapted from Stockholmsforsoket, 2006)

The price was the same for any vehicle such as lorries or cars. However, there were a number of discounts. These can generally be divided into two groups depending on if the vehicle could cross the cordon for free with or without a permit, listed below:

**Free from charge**

- Emergency Vehicles
- Buses with a Total weight of 14 tonnes or more
- Vehicles running on a fuel blend primarily consisting of alcohol.
- Diplomatic Cars
- Taxis
- Motorcycles
- Vehicles registered abroad
- Military vehicles

**Free from charge only with a permit**

- Vehicles with a disability parking permit
- Transportation vehicles with a total weight less than 14 tonnes
- Vehicles running partially or completely on electricity or gas other than LPG

As of 1 July 2007, the congestion tax was tax deductible for company cars and commuters and taxis were no longer exempted the fee. (Svenska Dagbladet, 2007 (URL); City of Stockholm, 2008 May)

The objectives for the trial were:

- To reduce traffic to and from the city by 10-15% during in morning and evening rush hours
- Better level of service in the Stockholm city traffic
- Reduction in emissions of carbon dioxide, nitric oxide and particulate matter
- City residents will experience a better city environment

(Swedish Road Administration, 2008a(URL))

Of the four goals, there were two regarding traffic impact and two environmental objectives. In fact, on the homepage of (2006 (URL))the name “environmental fee” is used parallel with “congestion tax.”

Stockholms short history of congestion tax comprises three major events:

- 2006, 3 January – 31 July: Trial period
- 2006, 17 September, Referendum
- 2007, 1 July: Implemented permanently

The congestions tax was one of three elements in the stockholm trial. The other two were an increase of the number of parking places (1500) outside the cordon and an increase of public transport consisting of 197 new buses in service six months before the trial. (City of Stockholm, 2006c & 2006d)

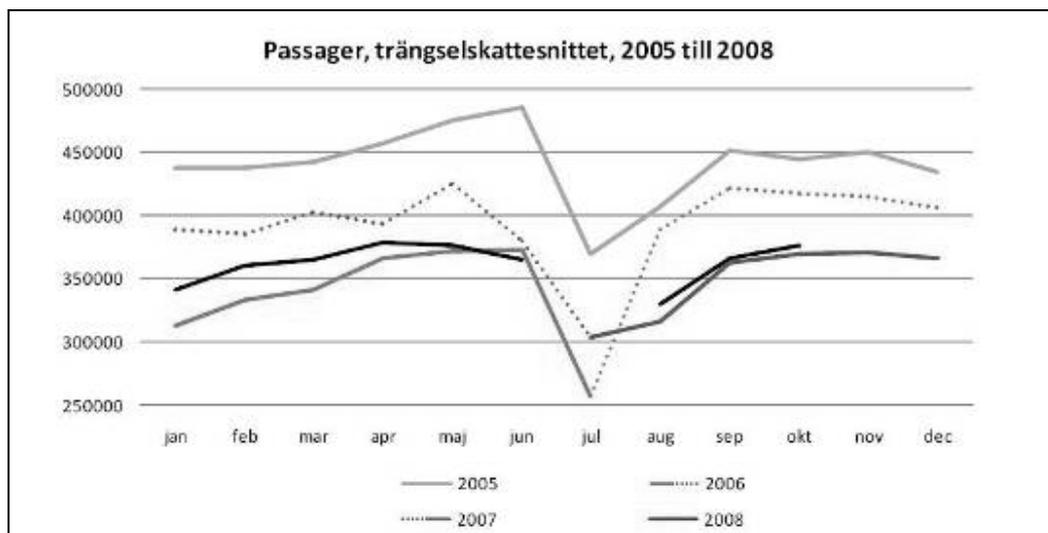
Capital costs were raised by the central Swedish government, even though the revenues collected were allocated to improvements in Stockholm. The revenue in the trial was redistributed to improve public transport. (Stockholmsforsoket, 2008 (URL)) The new Swedish government in 2006 decided that the revenues would be redistributed to road improvements overall. Of the revenue for 2008, approximately 50% would be allocated to improvements in public transport and the other half to general improvements in infrastructure. (Nordic Infrastructure, 2008 (URL))

#### **4.4.2 Effects**

The way of measuring the traffic flow in Stockholm was generally by counting the number vehicles crossing the cordon surrounding the levied area, thus, including both inbound and outbound traffic. The reports available compare the traffic flow during the trial with different times before, generally with the autumns in 2004 and 2005. As the trial was in spring in 2005 and there is a seasonal variation of traffic flow in Stockholm this further, complicates assessing the results.

##### **4.4.2.1 Cordon and zone**

The number of vehicles crossing the cordon for the charging hours overall reduced by 22% compared to the previous year. In actual numbers this was equal to approximately 100 000 less passages per day. The reductions for the morning peak (7.00am-9.00am) was 16% and in the evening peak (16.00-18.00) reduced by 24%. Remembering that one of the objectives of the scheme was to reduce the morning traffic with 10-15% and the evening traffic with the same, the objective was exceeded in both times. (2006b) Cars alone are reported to have reduced by 30% compared to October 2004 and by 20% when comparing to spring 2005. (City of Stockholm, 2006e & f)

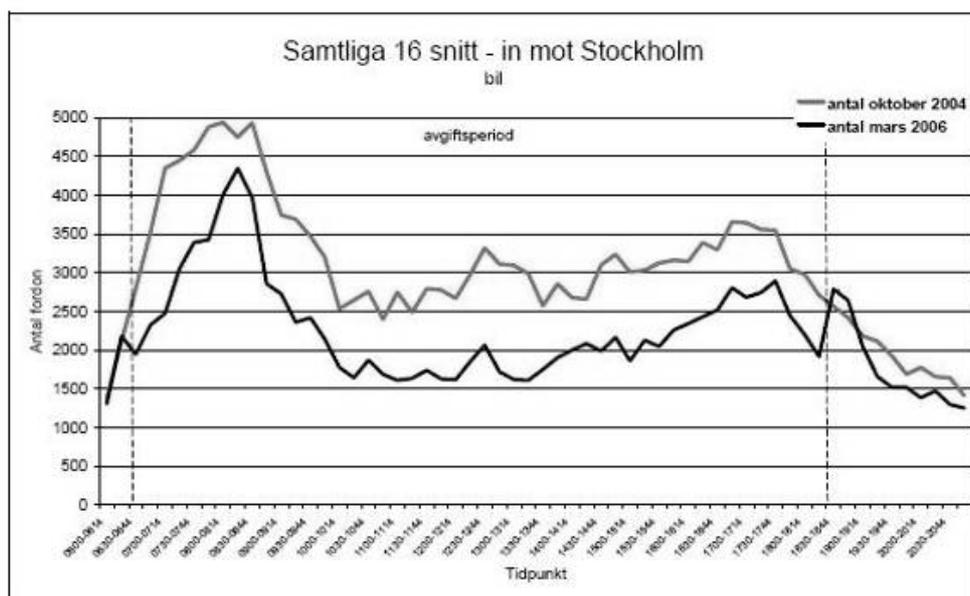


**Figure 18** – Number of vehicles leaving or entering the charged zone for the years 2005-2008. The dotted parts of 2006 and 2007 represent the time between the end of the trial period (July, 2006) and commence of the permanent tax (July 2007). (City of Stockholm, 2008b, p.1)

Figure 18 illustrates the traffic in the pre charging year 2005 and the impact of the tax for the first half of 2006, the second half of 2007 and in 2008. The drop in July can be seen for all years as an effect of lower traffic due to holidays. However, after the end of the trial, traffic was either the same or slightly lower than the pre charging year, related to significant road works in the central of Stockholm.

The scheme was reimplemented on a permanent basis in July 2007. For the first four months in 2008, in and outbound traffic increased by 9% compared to the trial period in 2006. There are several reasons for this such as economic growth, better weather conditions, the new rule for tax deductible cars, higher amount of cars classified as environment friendly. However, the traffic level was still 17 percent lower than for the same time in 2005. (City of Stockholm, 2008a)

The number of exempted vehicles represented 28% of all passages during the trial period. When the permanent scheme was implemented in July 2008, taxis (earlier representing 8% of all passages) were no longer exempted the fee. However, the number of environmental friendly cars grew from 3% during the trial to representing 12% in September 2008, resulting in that exempted vehicles represented the same share of all passages, as in the trials. The exemption of environmental friendly cars was planned to be removed 1 Aug in 2012. However, the growth was higher than predicted and this exemption was removed for cars registered after 1 January 2009, as it was a threat to the level of service. (City of Stockholm, 2008b; Swedish Road Administration, 2008b (URL), City of Stockholm, 2008 (URL))



**Figure 19** - Inbound traffic crossing boundaries for given times in Oct 2004 (grey line above) and in March 2006 (Black lower line). (City of Stockholm (2006d), Figure 1, p.42)

Figure 19 is one of few graphs providing inbound traffic only, in this case for cars entering the charged zone between 06.00 and 21.00. However, as cars represented approximately 90% of all vehicles tolled off the graph is assumed to be fairly reliable for the overall change in inbound traffic. (Author's Remark) As can be seen, the morning peak is both shorter than the peak in October 2004. Moreover, the evening peak is significantly lower than the morning peak. Lastly, there is a rapid increase at 18.30 higher than the measured traffic flow in Oct 2004. (City of Stockholm, 2006d)

The large reduction of entering vehicles during the period in between peak hours (even though the charge was half of the peak charge) is partly explained by the fact that drivers had to pay the higher charge when going back. (Eliasson et al, 2006)

Zone	Skillnad i %				
	Pb	Llb	Tlb	Buss	Totalt
06-09	-19,1	-17,4	-4,5	<b>34,8</b>	-17,4
09-15	-18,9	-12,3	-8,8	<b>17,3</b>	-16,9
15-18	-18,8	-19,3	-6,9	<b>21,3</b>	-17,8
18-06	-10,9	-13,5	-10,7	<b>7,1</b>	-10,7
00-24	-16,5	-15,0	-7,8	<b>18,4</b>	-15,5

**Table 11** – Changes for Cars (Pb) light goods vehicles (Llb), heavy goods vehicles (Tlb) and busses within the charged zone with and without congestion tax. (City of Stockholm, 2006d, p.78)

As can be in Table 11, illustrating the vehicle kilometers transported (vkt), cars (Pb), light (Llb) and heavy (Hlb) goods vehicles decreased while busses increased for all times, including non chargeable hours. There is no data for the charging hours only, however, the times 6.00-18.00 will be assumed to be fairly consistent with the charging hours even though the actual times were 6.30-18.30. According to this, the vehicle kilometers transported (vkt) within the zone were reduced by approximately 17% for the charging hours were cars reduced by approximately 19%. Buses saw the biggest increase of 35% in the morning peak and 17-21% for the other charging hours. Overall, the vehicle kilometer's driven for a day reduced by 15%. (City of Stockholm, 2006c)

#### 4.4.2.2 Congestion

Main roads within the charging zone and the main roads to central Stockholm were measured and compared to the previous year in the morning and afternoon peak. As shown in Figure 20, the excessive time in minutes/km reduced in all area,s in and outside the charged area. (Eliasson et al., 2008) The final report (2006c), summarizing the key finding from the trial, states that congestion on the major roads accessing the city had reduced by a third in the morning peak and by half in the afternoon peak. (Stockholms stad, 2006c)

Measures carried out by the Royal Institute of Technology (2006), show that reductions were lower inside the charged zone than for the main roads outside. (Bång & Moran, 2006)

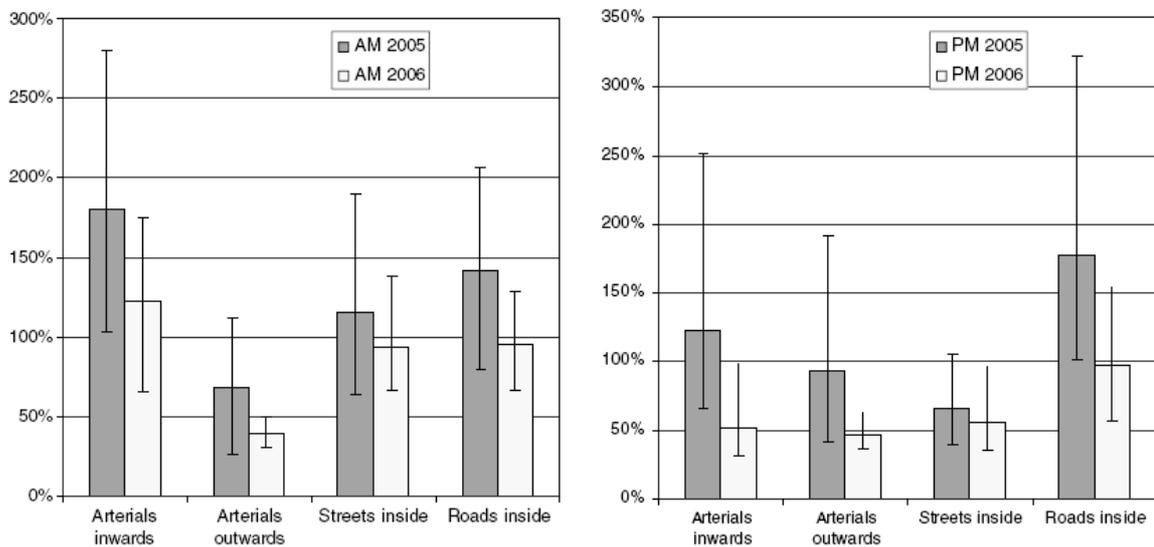


Figure 20 - Difference in excessive time for selected roads, morning time in 2005 and in 2006. (Eliasson et al., 2008, Fig 4, p.8)

#### 4.4.2.3 Public Transport

The demand for public transport was predicted to increase, as an effect of the congestion tax and was extended by 7% in fall 2005. Commuter trains were extended and the bus capacity was increased with more busses and new bus routes to the city. (Stockholm Public Transport, 2006) The number of passengers crossing the boundaries for the charging hours increased by 6% compared to 12 months earlier. However, according to estimations by Eliasson et al. (2008) 1.5 percentage point of the increase was related to higher fuel prices.

Overall, crowding on public transport increased slightly during the trials. This increase was principally seen at the underground service (representing over 50% of the trips undertaken with the public transport in Stockholm), related to that the metro was operating at maximal capacity already in 2005 and also experienced problems in 2006. Looking at the inbound metros for the morning hours 7.30-8.30am, the capacity was reduced while the number of trips increased by 24%. The bus capacity for the same time was increased according to the new demand of travelers. (Stockholm Public Transport, 2006a, 2006b) Eliasson et al. (2008) report that the number of standing passengers on buses was unchanged while commuter trains saw a minor decrease. There was no general increase in average speeds for inner city buses, as there was no change in the busschedules in 2006. (Eliasson et al., 2008) The punctuality was unchanged but the punctuality for buses arriving at their final stop was improved. Results from interviews with busdrivers in the innercity shows that 80% of the drivers thought that the level of service was better and that it was easier to follow the time table (City of Stockholm , 2006d). Buses with no fixed timetable crossing the cordon “experienced considerably time gains” and “there are signs that punctuality improved” (Eliasson et al., 2008, pp. 7).

Attitude surveys were carried out among passengers on public transport for the spring in 2005 and in 2006. As shown in Figure 16, the customer satisfaction decreased slightly between 2005 and 2006. For the new bus routes the customer satisfaction was higher for all three categories. (Casemyr, 2006)

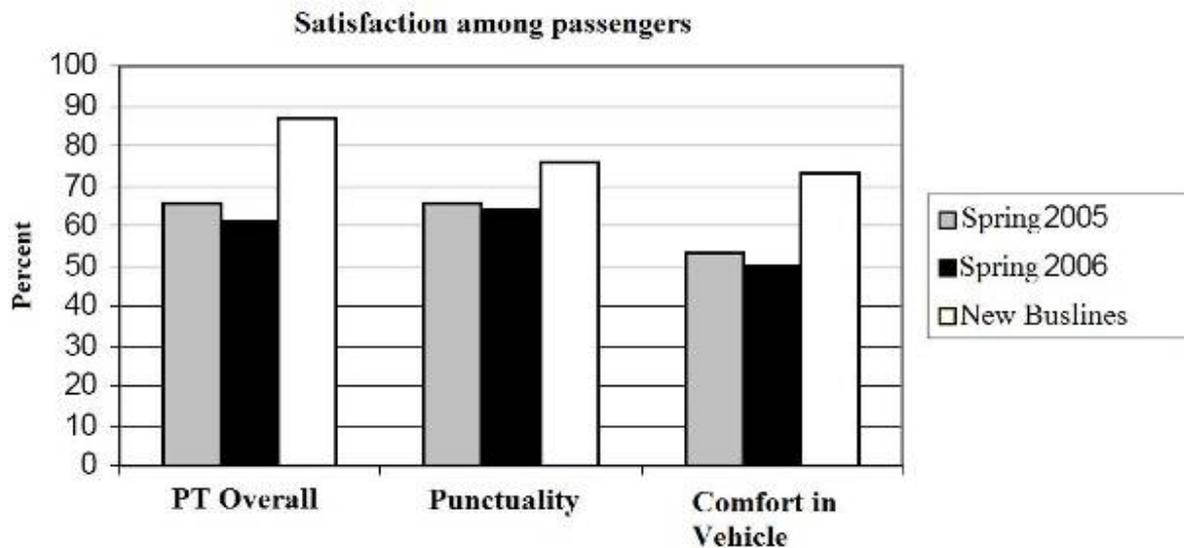


Figure 21 – Customer satisfaction for the springs in 2005 and in 2006. White column represents satisfaction for the new bus lines in 2006. (Stockholm Public Transport, p. 13)

#### 4.4.2.4 Modal Swap

Of passages counted during the trial, traffic overall reduced by 20-25%. When compared to spring 2005, cars alone reduced by 20% (80 000 passages, half of these changed to public transport) while public transport saw an increase by 5% (30 000 passages). Of the reduced cars trips, half of these were work related. Of these, over 90% changed to public transport. (City of Stockholm, 2006e) Moreover, the increase of walking and cycling is hard to interpret as these strongly vary with the season. The counting before the trial was carried out in October in 2005, while the trial was in spring 2006.

The mode share for Public Transport/Car was approximately 70/30 before commencing the congestion tax. There is no figure of the mode swap after commencing the charge. However, traffic reduced by 16%, in the morning peak. Assuming that cars saw the same reduction and all of these were work related. If 90% swapped to public transport, the new PT/car share would be maximum 75/25.

There was no evidence of increased car commuting or work from home. (City of Stockholm, 2006e)

#### 4.4.2.5 Traffic outside the charging zone

The traffic flow on the north-south free route (Essingeleden) was expected to increase when applying the congestion tax. To limit this effect, the road administration regulated three on-ramps with traffic lights. (Swedish Road Administration, 2005b) The traffic on Essingeleden increased between 0-5% when comparing the springs for 2005 and 2006. This increase was relatively small

when compared to general variations from day to day that can be bigger. (City of Stockholm, 2006c, 2006b) for the first four months in 2008 the traffic was 7% higher than for the same period in 2006. (City of Stockholm, 2008)

The Traffic on the west-east bypass (Södra Länken) increased by 18% for the first year. These results may seem high. However, the link was opened up in October 2004 and the traffic increase was related to the fact that the link was new, rather than an effect of the congestion tax. (City of Stockholm, 2006d) The traffic remained at the same levels for the first three months in 2007 even though there was no charge. For the same months in 2008 the traffic was unchanged but increased another 5% in 2008. (City of Stockholm, 2008)

#### **4.4.3 Equity Impact**

Of those affected by the toll, the main group was middle class that swapped to public transport. This is related to that low income takers were already on public transport before the trial started and that high income takers were less sensitive to an extra charge. The largest reduction in car travel was seen among students, unemployed and pensioners. (City of Stockholm, 2006d)

#### **4.4.4 Business Impact**

Daunfeldt, S.-O. et al (2008) investigate the possible impact on shopping malls and shops located within the area. The results indicate that these were not affected by the scheme. Reasons might be that malls were still opened after charging hours. Further, as parking fees were relatively high in the city it is likely that car users were high income earners and less sensitive to congestion pricing. City of Stockholm (2006d) states that it is difficult to draw any conclusions due to the short time of the trial and shopping behavior can change slowly. Lastly, there had been a general trend towards shopping outside the cities overall in Sweden that further complicates comparisons. The overall trend seen within the zone, has followed the trend overall for Sweden. (City of Stockholm, 2006d)

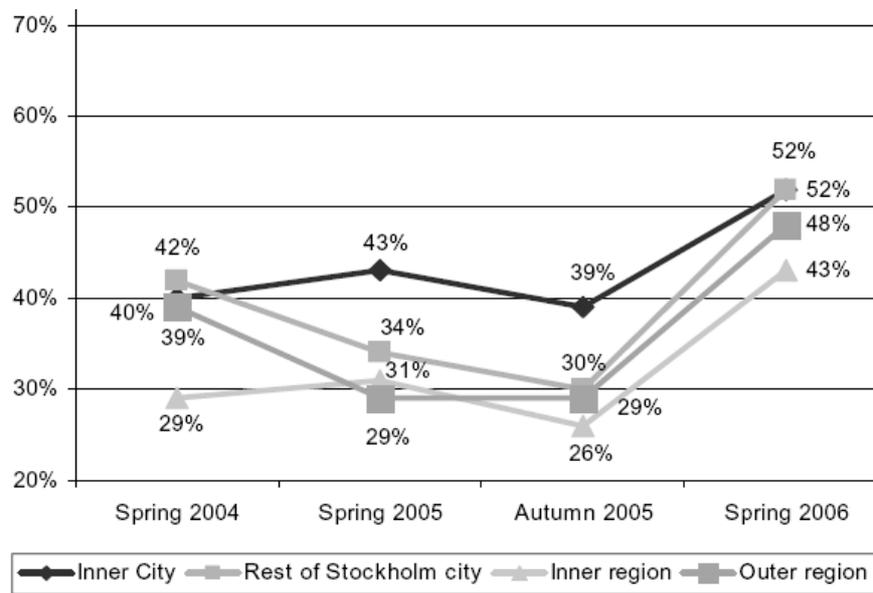
#### **4.4.5 Implementation process and public opinion**

Differently to the other schemes, the Stockholm congestion tax trial was a decision made by the Swedish central government and not by the local government in Stockholm. The charge levied on vehicles was equal to a tax from a legal point of view. Thus, the tax levied on vehicles would go to the central government, as local authorities in Sweden only can tax their own inhabitants. The trial was an effect of a political compromise in the 2002 general elections, backed up by two minor parties in a left wing coalition (Gudmundsson, H. et al., 2008). (Eliasson et al., 2008)

Attitude surveys were carried out before, during and after the trial. Generally, these showed that people's perception of the congestion tax was more positive after the commencement of the trial, as they could see the positive outcomes such as personal benefits. The number of respondents agreeing on that "the congestion tax causes major problems", reduced from 40% before the trial to 20%

afterwards (including the “minor problems” the reduction was: from 73% to 52%). Furthermore, 35% said that they were more positive to the congestion tax after the trial while 15% said that they were more opposed to it. (City of Stockholm, 2006d)

The changes in support for different areas of Stockholm are illustrated in Figure 22 where a clear increase in support can be seen for all areas, after the commencement of the trial in spring 2006. Residents in the inner city were most positive to the trial even though they on average paid more charges and experienced smaller time gains. This may be explained by the value of a better environment or reduction in accidents. (Eliasson et al., 2006)



**Figure 22** – The percentage of people responding “rather likely yes” or “very likely yes” for different areas of Stockholm if they were to vote in a referendum today on a permanent implementation. (Hiselius et al., 2008, Figure 7, p. 11)

The public in the city of Stockholm were consulted in a referendum held after 7 months of trial, regarding a possible permanent implementation of the scheme. The inner city (mostly located within the charged zone) voted in favor (53% yes; 47% no) while all other voting areas were opposed to the idea of implementing the tax permanently (Including all votes the result was 48% yes; 52% no). However, the municipalities not arranging referendums were overall supporting the scheme and stated that it was up to the inner city to make the decision. Thus, the result was not entirely picturing the overall opinion and was difficult to interpret. Because of legislative reasons the decision would be made by the central government.

The referendum coincided with the Swedish general elections and was won by the opposition. The new government (that was previously opposed the congestion tax) decided to make it permanent. However, in an attempt to compensate the negative impacts on the municipalities around Stockholm the new government announced that the revenue raised would now be used for road investments overall. (Eliasson et al., 2008)

## 4.5 Milan

Milan is the second biggest city in Italy with a city population of 1.3 million and a density higher than 7000 persons/km<sup>2</sup>. The urban area comprises nearly 4 million people with a density of nearly 2000 people/km<sup>2</sup>. (Wikipedia, 2008e (URL))

Italy had, in 2007, one of the highest vehicle ownership rates in the world (656). Of the assessed European countries by Dargay, Gately and Sommer (2007), Italy was only exceeded by Iceland and Luxemburg. The private vehicle ownership for Milano in particular is 594. (Ambiente Milano, 2008(URL))

Cheshire, Evans and Gorla (1998) report that Milan had serious congestion and according to a study by Legambiente and Ambiente Italia (2007) Milan had the third highest particle matter (PM10) in European cities (NY Sun, 2008(URL)). The city has tried restriction measures in order to tackle congestion and pollution. Between 1985 and 1996 cars were restricted from the historical centre, an area equal to 1.6% of the whole of Milan. The scheme lasted until 1996. After that, other restriction measures have been tried for the zone. (Cheshire, Evans & Gorla, 1998)

*Legambiente and Ambiente Italia* (2007) report that the mode share for private vehicles/public transport was 72/28, however, without saying if this is during morning peak or overall.

### 4.5.1 Facts about the scheme

The Milan Eco Pass was introduced on the 2 January in 2008 as a one year trial (Transport Environment, 2008(URL)). The main objectives were to:

- *make the air cleaner by reducing PM emissions in the Cerchia dei Bastioni by 30%, with a positive fallout on the surrounding areas of the city as well;*
- *relieve congestion by reducing the number of incoming cars by 10% and thereby speeding up public transport in the area;*
- *boost public transport by reinvesting all Ecopass charges in sustainable traffic and a sustainable environment.*

(Quoted in Info Brochure, p.1, Milan Council, 2008)

The operating hours were 7.30am – 7.30pm, Monday to Friday. There were 43 entry points to the 8 km<sup>2</sup> big area (BBC, 2008) The charge depended on the pollution class of a vehicle and there were three different charges, €2, €5 or €10. Furthermore, multiple entrance cards could be purchased for passenger vehicles with discounts between 40 and 50 percent for up to 100 annual entries. Residents living within the area are entitled to purchase an annual pass, equal to 25 entries.

Two pollution classes (containing vehicles such as electric or hybrid cars) were exempted the fee, see Table 12 below. In addition, scooters, mopeds, motorbikes and vehicles carrying disabled passengers are all free from charge. (Municipality of Milan, , 2008a) The same exemptions applied to public transport, Taxis and emergency vehicles. (Municipality of Milan, 2008b)

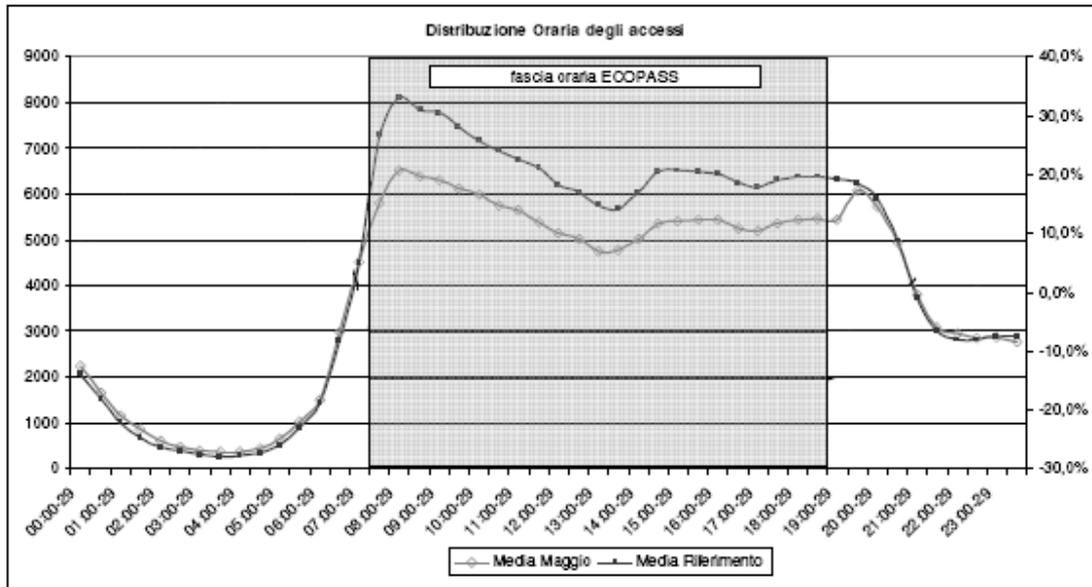
POLLUTION CLASS	VEHICLE EURO CATEGORY	DAILY ECOPASS
CLASS I	gpl - methane - elettrico - hybrid	FREE ACCESS
CLASS II	Euro 3, 4 or more recent petrol cars and goods vehicles Euro 4 diesel cars and goods vehicles without particulate filter (exempt for 6 months as from 2 JANUARY 2008) Euro 4 or more recent diesel cars and goods vehicles with approved particulate filter	FREE ACCESS
CLASS III	Euro 1, 2 petrol cars and goods vehicles	€2
CLASS IV	pre-Euro (Euro 0)* petrol cars and goods vehicles Euro 1*, 2 and 3 diesel cars Euro 3 diesel goods vehicles Euro 4 and 5 diesel buses	€5
CLASS V	pre-Euro (Euro 0)* diesel cars pre-Euro (Euro 0)*, Euro 1* and 2 diesel goods vehicles pre-Euro (Euro 0)*, Euro 1*, 2 and 3 diesel buses mopeds, scooters and motorbikes*	€10
There is no Ecopass charge for mopeds, scooters and motorbikes; vehicles carrying disabled passengers and/or bearing a disabled passenger badge.		
N.B. pre-Euro (Euro 0) and Euro 1 diesel vehicles, pre-Euro (Euro 0) mopeds, scooters and two-stroke motorbikes are anyway barred from entering or circulating within the territory of the municipality of Milan, from 15/10/2007 to 15/4/2008, from 7.30am to 7.30pm from Monday to Friday (except Public Holidays), in compliance with regional bylaw no.5291 dated 2/8/2007.		

Table 12 – Showing the different charges depending on its pollution class (Milano Council, 2008, p.6)

The charged area was located inside the inner ring road (Cerchia dei Bastioni). The area of 8km<sup>2</sup> represented 5% of the city area (The Sun, 2008(URL))

Eco Pass was part of a 30 measure program worth £3.5 billion financed by the central and regional government and Milan including measures such as doubling the metro network by 2015, new bus lanes, financing car sharing and cycle paths etc. (The Sun, 2008(URL); Municipality of Milan, 2008a (URL)) The public transport excluding the metro, was increased with 40 new lines and 1300 daily journeys. (Municipality of Milan, 2008b)





**Figure 24** –The changes in traffic entering the charged area on an average day in June compared with a pre-charging day.. (Adapted from Musicality of Milan, 2008d, p.7)

There is no report yet summarizing the traffic flows on an average day. However, most monthly reports show a similar traffic pattern throughout a weekday such as illustrated in Figure 24, showing an average weekday in May, 2008 compared to a pre-charging day. The largest reduction in absolute numbers can be seen in morning hours, and then followed by an even reduction for the midday and evening hours. Lastly, there was an increase in traffic immediately after charging hours, however, still lower than pre-charging levels.

#### 4.5.2.1 Congestion

For the first 11 months, congestion had fallen with 25% in the morning peak within the charging zone. This was equal to an increase of the average speed of 4.0 percent. The Municipality of Milan (2008c) claims that congestion was not a severe problem before the introduction of Eco Pass. Further, the shape of the city makes it difficult to reach high speeds even for free-flow conditions. For the same period, the PM10 emissions from cars reduced by 23% (Municipality of Milan, 2008c)

#### 4.5.2.2 Public Transport

Prior to the introduction of the charging scheme public transport (excluding metro) was extended with 40 new lines equal to 1300 daily trips. The average speeds for public transport (buses and trams) inside Cerchia dei Bastioni increased by 6% to 9.4km/min. The variation was above the reference value for all months and varied between 0 and 14% excluding August (29.5%) when people were on holidays. The metro saw an average daily increase of 7.3% (19100 passengers) and

when comparing October and November to the reference period in October and November for the previous year the increase was 18%. (Municipality of Milano, 2008c)

#### **4.5.2.3 Modal swap**

The reduction in vehicles entering the area was caused by drivers avoiding the charge. Of these

- 35% diverted around the area
- 17% changed to cars exempted the fee
- 48% changed to public transport (Municipality of Milan, 2008c)

#### **4.5.3 Implementation process and public opinion**

The major Ms. Moratti faced opposition from her own political allies and the original plan of levying an area equal to 60 km<sup>2</sup> had to be scaled down to only 8 km<sup>2</sup>. The scheme was planned to commence in October 2007 but was eventually postponed. Local residents were initially not subject to any discounts. (New York Sun, 2008 (URL)) The city was evenly divided at the introduction of the charges. (BBC, 2008 (URL)) The board of the Municipality of Milan decided to extend the trial another year and announced that for the first months of 2009 public consultations would be carried out to assess the public attitudes towards the ecopass scheme. (Municipality of Milan, 2008b (URL))

## **4.6 Auckland**

This section assesses the possible implementation of road pricing in Auckland. A study was carried out in 2006 (Auckland Road Pricing Evaluation Study, ARPES) evaluating possible schemes with reduction of congestion as the first objective and raising revenue as a second. Even though there is no target year, the ARPES report assesses the conditions for 2016. At current, the road authority is also studying the possible implementation of a scheme with revenue as first objective. No scheme or proposal has been recommended yet. This section will firstly assess which scheme or schemes are likely to be the most suitable of the current proposals. This or these schemes will be compared relatively to the other four cities in the analysis chapter in order to contribute to the discussion regarding the implementation of a suitable scheme in Auckland.

### **4.6.1 New Zealand**

Auckland is located in the northern part of the north island of New Zealand. The country has a population of about 4.3 million and an area of 279.000 km<sup>2</sup>, giving a density of 15 persons/km<sup>2</sup>, one of lowest densities among OECD countries(Wikipedia, 2008f). The low density and a topography similar to Norway's makes infrastructure expensive in New Zealand. New financial solutions have been tried recently in the country in order to make infrastructure more efficient. (Author's remark)

In 2003, a new bill was passed in the New Zealand government called the Land Transport Management Act. The act enabled the use of tolls, in order to advance projects through debt financing, if the tolls are used only in order to pay back the road in question. Furthermore, the road administration (New Zealand Transport Agency) must have a high degree of support from affected communities before constructing a toll road. At current, a new motorway (Alpurt B2) is under construction north of Auckland through debt financing that partly will be paid back by road tolls. (Homepage of Northern Gateway Alliance, 2008)

### **4.6.2 Auckland**

Auckland is the major city of New Zealand with a population of 1.300 million people and a growth rate of 1.5% (ARPES, 2006). The population represents over a third of the population of New Zealand and Auckland's density is 1209 persons/km<sup>2</sup>. (Wikipedia, 2008; MoT, 2006a)

The low density and low usage of public transport makes Auckland one of the most car dependent cities in the world today (Mees & Dodson, 2006). The region contains geographic characteristics such as waterways and harbors that impose constraints on the transport system that is confined to narrow corridors with few alternatives. (MoT, 2006b)

The number of cars and vans in Auckland were 721 000 in 2004 equal to 555 cars per 1000 people. The mode share for public transport in 2005 was 7% in the AM peak and is predicted to increase to

11% in 2016 (the share of car trips for the same year is predicted to be 73% resulting in a PT/Car share of 13/87 for the AM peak). (MoT, 2006a & b) In 2006, 68% of all trips to work were by car while 8% were by public transport. This can be compared to the metropolitan of Stockholm where the figures for car and public transport were 49% and 33%. (ARTA, 2008 (URL); Automobile Association, 2008 (URL), Stockholm Public Transport, 2007). Traffic in Auckland is predicted to grow with an average annual rate of 1.5% for the years 2006-2016. (MoT, 2006b)

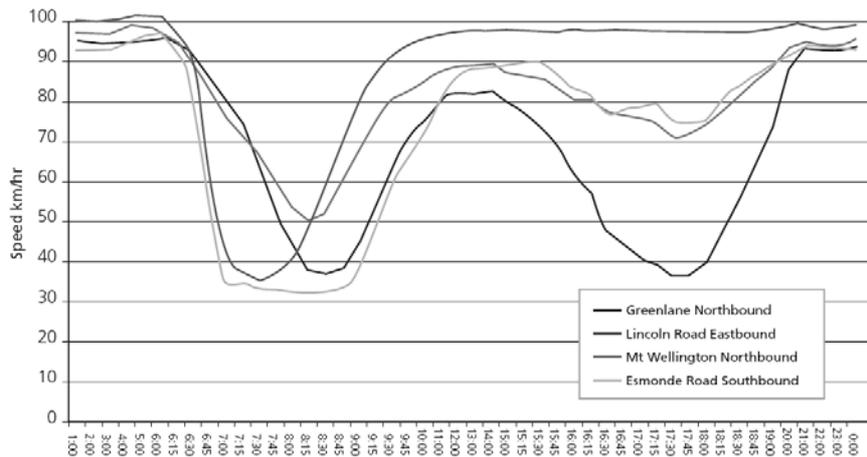


Figure 25 – Average Speeds on motorway during a weekday. (ARTA, 2007, Figure 3.3, p.9)

Figure 25 illustrates the average speeds for the main roads in Auckland. As can be seen, there is a reduction in speed on all roads in the morning peak while the reductions are generally smaller in the afternoon peak (ARTA, 2007). 74% of residents in Auckland identified reducing congestion as “very important” and another 20% as “important”, while 80% of businesses in Auckland thought it was “very important” and the remainders as “important”. (MoT, 2006a)

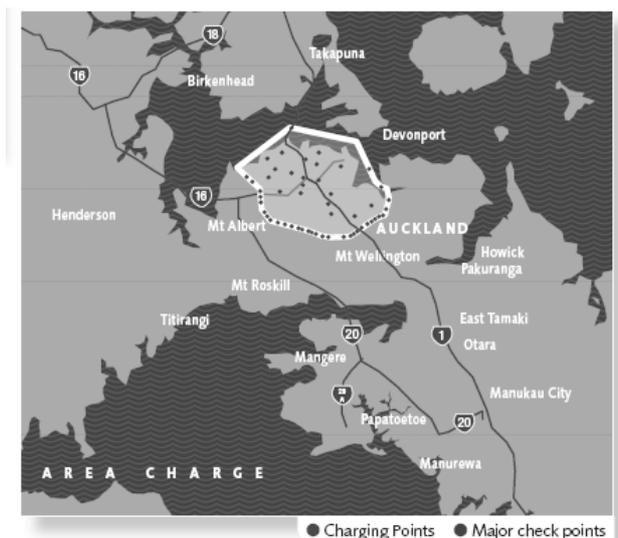


Figure 26 – Map of Auckland with the Western Ring Route (SH20, SH16 and SH18) completed and the proposed “Area scheme”. (MoTb, 2006b)

The main road, State Highway 1 (SH1) goes through the central area. There are several major road works going on in Auckland including a new bypass, *the Western Ring Route*, see Figure 26. Thus, if congestion pricing would be implemented in central Auckland after the completion of the bypass, this would be the main free alternative for drivers wishing to avoid the charge.

### **4.6.3 Facts about the proposal**

A study was carried out in 2006 under the name Auckland Road Pricing Evaluation Study (ARPES). The study assessed five different schemes in order to reduce congestion in Auckland: four different types of congestion pricing schemes and one parking levy scheme. The schemes that were assessed had reducing congestion as a primary objective and to raise revenue as a secondary objective. Furthermore, all schemes were assessed with a charge levied under the morning peak only (6.00am-10.00am) under the assumption that the reduction in the morning peak would reduce congestion for the rest of the day. (MoT, 2006b)

The ARPES report (2005b) carried out a study in 2005 including 600 Auckland residents and business. The support for introducing any of the schemes was 38% while 48% opposed the idea. However, a submissions analysis was carried out in 2007, seeing 75% of the people consulted opposing a possible congestion scheme. “Inadequate public transport, the lack of a north/south “ring road”, the inequity of charging for the use of roads that are perceived to have been funded through existing taxes, and the fairness of applying a flat road pricing structure across all groups in society” were some of the reasons (Quoted from Homepage of MoT New Zealand, 2007). The Ministry of Transport later decided to conduct a study of a scheme with the main objective to raise revenue and to reduce congestion as a second objective. (MoT, New Zealand, 2007 (URL))

### **4.6.4 Analysis and discussion of proposed schemes**

Currently there are 5 schemes with congestion as the first objective and one revenue scheme under consideration.

Of the congestion schemes, there is one parking scheme using raised parking levies as a measure to tackle congestion. However, as stated earlier in the report this measure punishes stationary traffic, thus, only a part of the congestion issue. In addition, it is difficult to implement this measure as there are many private parking areas. The second proposed scheme tolls the main highways during the morning peak. This scheme would have minimal social impact as there would be free alternatives. On the other hand, it would divert significant traffic to areas that are most likely less suitable to handle traffic congestion.

The three remaining congestion schemes charge different selected areas in Auckland, all containing the central business district. One scheme, “the single cordon” would cover north-south main roads and leave no free alternative for drivers not wanting to stop in Auckland. There is no such congestion scheme implemented so far and it is unlikely that such a scheme would be implemented

Auckland, considering the high car use. Thus, remaining are two proposed schemes, one "Double cordon scheme" and one "Area scheme". Shown in Figure 27, the Double cordon scheme would have the free bypass *the western ring route* following the western cordon. The Area scheme is equal to the inner cordon. However, the Area scheme would charge NZ\$5 as a one day fee for driving in the zone while the Double cordon scheme would work as a passage toll system charging NZ \$3 dollars per passage with a maximum charge per day of NZ\$6. (NZ\$1≈0.40€, Jan, 2009 exchange rates)

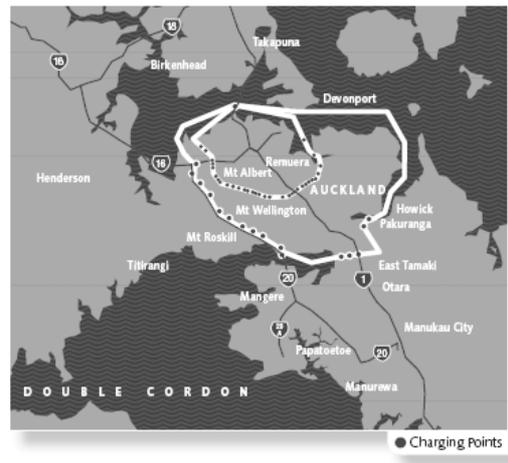


Figure 27 – The Double cordon scheme proposal charging vehicle NZ\$3 for crossing one of the cordons, the area scheme proposal would be equal to the inner cordon only covering all trips within the area (ARPES, 2006b, p.4)

The Auckland central business district (CBD) is located inside the inner cordon. Many low income households are located south of Auckland. These are likely to be impacted more by the Double cordon scheme than the area scheme, capturing only the most central area of Auckland. Moreover, the area scheme is estimated to reduce the number of vehicle trips by 42% within the area, while the Double cordon scheme would reduce the number of passages by 36%. Below is presented the possible impact of both schemes: (MoT, 2006b)

	Veh. Trips No Pricing	Trips Reduction	Total Trips affected (7.00-9.00am)	% of Vehicle fleet in Auckland	Congestion Reduction
<b>Double Cordon</b>	183 000	-36%	33%	22%	-40%
<b>Area</b>	217 000	-42%	40%	26%	-30%

Table 13 – Number of vehicle trips affected in zone, the vehicle reduction within the zone, percentage of total trips affected in Auckland, percentage affected of the total vehicle fleet in Auckland and reduction in congestion on the Auckland Network. All are for the hours between 7.00am-9.00am. (ARPES, 2006b), (% of Vehicle fleet is calculated by dividing the number of trips affected by the number of vehicles in Auckland)

As shown in Table 13, the Area scheme is more efficient in reducing vehicle trips. Being a smaller area with a larger traffic reduction in actual numbers, the Area scheme is predicted to divert more traffic from the charged area and increase congestion outside the zone. Thus, the estimated impact on congestion in Auckland overall is lower than for the Double cordon scheme. The number of

public transport trips in Auckland for the 7.00-9.00am time is predicted to increase from 83 000 (No charging scheme) to about 105 000 trips for 7.00am-9.00am (27%) for both schemes. (MoT, 2006b)

In summary, the double cordon scheme is the most efficient scheme in terms of reducing congestion in Auckland. The Area scheme, would still be more efficient inside the zone, however, congestion is likely to increase outside the zone. The area scheme would have less social impact as the area is equal to the inner cordon only and fewer households would face the charge.

There is no information regarding the revenue scheme currently being assessed.

## 5 Analysis of case studies

This chapter compares the different cities, overall, for the first year of operation. Stockholm and Milan were both trials during the assessed period of time. In the case of Singapore, the charging hours analyzed are 7.30-10.15am. In some cases the times 7.30-9.30am (first month) are analyzed due to lack of data for the other time. The section “adjustments and changes” analyses possible changes in scheme after the first year. Boxes with the acronym “ND” mean that no data is available. It should be stressed that several of comparisons in this chapter aims to compare the schemes relatively, rather than giving an exact figure. Lastly, in the analysis chapter, the conditions in Auckland and predicted results from the ARPES report are compared to the other cities.

### 5.1 Conditions in the cities before scheme implementation

	Singapore <1975	London <2002	Stockholm <2006	Milan <2007
<b>Population (Million)</b>	2.3 (1975) 4.4 (2007)	7.9 (2006)	1.252 (2006)	3.9
<b>Density (People/km<sup>2</sup>)</b>	3000 (1975) 6000 (2007)	4 700 (2006) (Greater London)	4 200 (City) 3 313 (Urban)	7100 (City) 1900 (Urban)
<b>Car ownership (Per capita)</b>	≈60 (1975) 90 (2007)	330 (2008)	370	594
<b>Mode Share – AM Peak</b>				
Car/PT	63/37	12.5/87.5	30/70	ND
Car/Bus	63/37	33/67		

Table 14 – Initial conditions in the cities before implementing the schemes.

As shown in Table 11, London and Stockholm show similar conditions in terms of density, car ownership and mode shares. Milan and Singapore have higher densities. Remembering that the density of Singapore represents the whole country the density can be regarded as fairly high, similarly to the central of Milan. Further, even if there are no data for the mode share in Milan in the morning peak, the high car ownership indicates a low usage of public transport, which is similar to Singapore in 1975.

## 5.2 Scheme Design

	Singapore 1975	London 2003	Stockholm 2006	Milan 2008
<b>Other measures</b>	PT increase Park & Ride	PT increase	PT increase Park & Ride	PT increase
<b>Charge varies by:</b>	Singapore 1975	London 2003	Stockholm 2006	Milan 2008
<b>Vehicle type**</b>	No	No	No	No
<b>Time</b>	No*	No	Yes	No
<b>Place</b>	No	No	No	No
<b>Passage/Day fee</b>	One Fee	Day Fee	Passage	Day fee
<b>Principal Objectives</b>	Congestion	Congestion	<ul style="list-style-type: none"> <li>• Congestion</li> <li>• Environment</li> </ul>	<ul style="list-style-type: none"> <li>• Environment</li> <li>• Congestion</li> </ul>
<b>Times</b>	M-Sat 7.30am-10.15am	M-F 7.00am-6.30pm	M-F 6.30am-6.30pm	M-F 7.30am-7.30pm
<b>Exemptions:</b>				
<b>Residents</b>	No	90%	No	Annual Card
<b>Other</b>	Car pools, Trucks	No	No	Multiple Entrance Discounts
<b>Affected Area</b>	6-7 km <sup>2</sup>	22km <sup>2</sup> (2003)	34.5 km <sup>2</sup>	8 km <sup>2</sup>
<b>% of Urban Area</b>	1.0%	1.4%	9%	0.4%
<b>% Affected Cars in Urban area</b>	30%	8%	20%***	7%****
<b>Free By Passes</b>	Yes	Yes	Yes	Yes

Table 15 – Scheme Design, Notes: *\*The charge is for morning hours only. Thus, it could be claimed that the price varies during the day. \*\*Refers to space occupied, passenger car unit (pcu) \*\*\*Number of passages per car per day was 3.2 (City of Stockholm, 2006e). Thus, the number of daily passages for cars was divided by 3.2. The number of entering cars in London and Milan are assumed entering 1.6 times a day and cars in Singapore 1, as this scheme was operating during morning hours only. \*\*\*\*Used the vehicle ownership for Italy (656) per 1000 inhabitants and compared to the total amount of entering traffic, as there is no data available about reduction for cars only.*

The theoretical model assumes an unchanging traffic flow during the day. However, in reality, traffic may vary in both time and place and by vehicle type. (Jones, 1998) When the schemes were implemented no scheme had any variation in charge in terms of vehicle type (i.e. car or truck) or by place. Stockholm had higher charges for peak hours while Singapore only charged for the morning peak. Moreover, Stockholm was the only scheme where the charge initially was based on per passage.

Looking at Singapore in 2009, the charge was based on type of vehicle and the time of day. In addition the charge was based on per passage. Some inbound roads and places inside the charging zone were tolled in peak hours.

All cities extended their public transport fleet as the schemes were implemented. Singapore and Stockholm increased their number of parking places outside the charging zones.

Of the four schemes assessed, Singapore and London have congestion as the principal objective. A CO<sub>2</sub> based charge was proposed in London in 2008 but abandoned later. Stockholm and Milan had both traffic and environmental objectives.

Regarding the residents living inside the zone London has the highest discount (90%). Milan provided an annual fee equal to 25 daily entries, a theoretical discount up to 90% under the assumption of 250 working days a year. For Stockholm and Singapore any vehicle could drive within the zone for free but had to pay when leaving.

One way of illustrating the scale of the impact on the urban area is by calculating the share: Scheme Area divided by the Urban Area. Stockholm (9%) had the largest share while the others were all below 1.4%.

Another way of illustrating the scale of impact, is by dividing the total cars affected (tolled or tolled off or exempted the fee) of the total car fleet in the urban area. The shares were largest in Singapore (30%) and in Stockholm (20%). The figures were lower in Milan and London.

All schemes had free roads that drivers wishing to avoid the charge could take. All schemes had exemptions for emergency vehicles, disabled people and public transport. Singapore had several exemptions for e.g. motorcycles and carpools. Milan was the only city offering a multiple entrance discount. Moreover, Milan was most likely the scheme with the lowest share of entering traffic that was subject to a charge (42% when commencing the charging scheme).

### 5.3 Demand Response

This section contains the demand response for the first year, shown in *Table 16*. Thus, long term progress in traffic demand will be analyzed in section “adjustments and changes”.

	Singapore 1975 7.30-9.30am	London 2003	Stockholm 2006*	Milan 2008
<b>Target: Traffic Reduction</b>	- (25-30%)	- (10-15%)	- (10-15%) AM/PM	-10%
<b><u>Actual Reduction:</u></b>				
<b>Traffic - Overall</b>	-45%	-14%	-22%	-14%
<b>Traffic - AM Peak</b>	-45%	ND	-16%	ND
<b>Cars - Overall</b>	-75%	-36%	-22%	ND
<b>Cars – AM Peak</b>	-75%	-20%	ND	ND
<b>Mode Share- AM Peak</b>				
<b>PT/Car –Before (AM)</b>	37/63	87.5/12.5	70/30	ND
<b>PT/Car- After (AM)</b>	50/50	89/11**	75/25***	ND
<b>Mode Change</b>				
<b>To Public Transport</b>		50-60%	50%	48%
<b>Diverted around zone</b>		20-30%	ND	35%
<b>Congestion</b>	-100%	-30%	- (15-30%) AM	-25%
<b>Average Speed</b>	Improved	+20%	Improved	Improved

*Table 16: \*Measures passages, all other measures entering traffic. \*\*Estimated, see chapter “London”, \*\*\*Estimated, see chapter “Stockholm”*

Singapore experienced the biggest change in both traffic and car reduction compared to the other cities. The difference is even bigger when considering that reductions in London and Stockholm appears to have been lower in the morning peak. The same pattern can be seen in the change of mode share, where the share of Cars reduced by 13 percentage points. According to the estimations, the car shares in Stockholm and London reduced by 5 and 2 percentage points. In the cities supporting data for modal swap, about 50% of the drivers tolled off transferred to public Transport.

London was the only city where the actual traffic reduction was according to the prediction. The other three cities exceeded their targets. All cities generally increased average speeds and reduced congestion

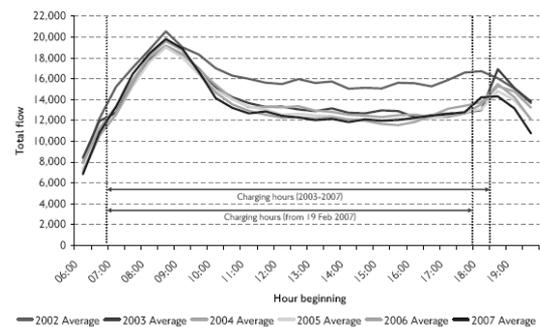
### 5.3.1 Traffic Diversion

#### 5.3.1.1 Time

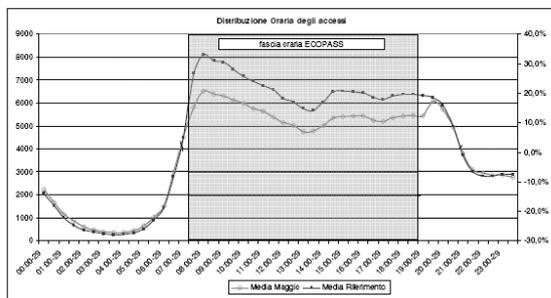
##### Singapore 1975

<b>7.00-7.30am</b>	<b>7.30-9.30am</b>	<b>9.30-10.00</b>
18%	-45%	18%
<b>7.00-7.30am</b>	<b>7.30-10.15am</b>	<b>10.15-10.45am</b>
5.4%	-49%	-12.4%

##### London 2003



##### Milan 2008



##### Stockholm 2006



The three graphs illustrate the impact on traffic entering the charging areas in Milan, London and Stockholm (cars only) compared to pre-charging conditions. As can be seen, all cities had initially a higher peak in the morning hours than in the evening. The peak was narrowed in Stockholm and London and both cities saw the largest reductions in the period in between peak hours (Even in Stockholm despite that the charge was lower between peak hours). In addition, all three cities experienced a new peak during the 30 min after charging time. In Stockholm and London this peak was higher than traffic levels the year before. In London, however, this peak decreased in the following years.

There is no graph illustrating the traffic impact for the first scheme in Singapore. The city experienced a significant increase in traffic (18%) before and after charging hours. The results are for the first month, after this the charging time was extended half an hour. When comparing the traffic flows half an hour before and after (for the years 1975 and 1976) these were (5.4%) and (-12%).

### 5.3.1.2 Place

For the bypasses or roads surrounding the charging zones traffic increased in London, Singapore and London. These were relatively small in London and Stockholm and road works had been carried out in advance to meet the expected increase in demand. In Singapore, travel times for all modes increased as traffic rose outside the zone. There is no figure for this in Milan more than that traffic has reduced by 4% outside the zone. Traffic reduction and diversion were similar to London.

Inbound roads, however, saw positive results in terms of reduced congestion or increase in average speeds in Stockholm, Singapore and London.

### 5.3.2 Public Transport

	Singapore 1975	London 2003	Stockholm 2006	Milan 2008
<b>Capacity Increase</b>	Yes	Yes	Yes	Yes
<b>Average Speed</b>	Worsened	Improved	Improved/Unchanged	Improved
<b>Punctuality</b>	ND	Improved	Improved/Unchanged	ND
<b>Crowding</b>	ND	Slightly increase	On Metro	ND

Table 17 – *The effect on public transport.*

As can be seen in Table 17, all four cities increased their capacity either before or when introducing congestion pricing. Thus, this expansion did not come from revenues collected from the drivers paying the congestion price.

Looking at the average speeds for buses, there are positive results from Milan and initially in London. The average speed in Singapore was reduced. In Stockholm, Inner city buses did not experience any general average speed increase, partly explained by the fact that time tables were unchanged when the scheme was commenced. The punctuality was improved in London and for buses entering Stockholm.

Furthermore, the number of passengers increased on the London buses but the passengers' perception of crowding was, overall, unchanged after commencing the charge. In Stockholm, crowding increased on the metro. There is no figure for this in Singapore but the city experienced the biggest swap in mode share between cars and public transport indicating that crowding probably increased.

### 5.3.3 Adjustments and changes

This section investigates possible adjustments after the first year of the scheme operation, shown in Table 18.

	Singapore*	London	Stockholm	Milan
1	Extension in time (7.30-10.15am)	Raise in charge from £5 to £8	Change of revenue objective**	No change
2	Evening hours (14.30-16.30) charged	Extension of Zone**	Exemptions for Taxis, removed	
3	Midday Hours charged		Exemptions for Environmental friendly cars removed	
4	Inbound Routes to charging zone			
5	Electronic Road Pricing, Passage tolls			

*Table 18 – adjustments and changes after the implementation. \*Note, even if not stated here. Singapore has seen a number of removals of exempted vehicles including car pools and trucks. In addition, the price has been changed and adjusted several times. \*\*Change due to a political reason rather than adjustment to new traffic demands*

Singapore has gone through major changes and adjustments during more than 30 years of operation. The first adjustment was to levy evening hours as the predicted mirror effect never occurred. A midday scheme was implemented as traffic levels were higher during these hours than in the morning and afternoon hours. In addition, inbound roads were subject to charge in the morning peak and Electronic road pricing was implemented in order to charge vehicles more accurately. London that has currently operated for 6 year raised the charge in 2005 by 60%. Stockholm removed the exception for taxis and environmental friendly cars, where the latter saw an increase higher than was initially predicted. Similarly in Singapore, trucks increased by 127% during charging hours and the exemption was later removed followed by the removal of other exemptions.

## 5.4 Economic and equity impact

The business impact is assessed for the whole time of scheme operation. As the scheme is relatively new in Milan there is no information available. As there is no information regarding the number of residents living inside the charging zone, an indicator is by calculating the affected area divided by the urban area. With this equation, it is possible to assess the percentage of urban people likely to benefit from environmental improvements, i.e. the city dwellers. Please note that these calculations are applied in order to assess the cities relatively rather than giving an exact figure.

	Singapore	London	Stockholm	Milan
<b>Times</b>	M-Sat 7.30am-10.15pm	M-F 7.00am-6.30pm	M-F 6.30am-6.30pm	M-F 7.30am-7.30pm
<b>Followed General Economic Trends</b>	Yes	Yes	Yes	ND
<b>Affected Area</b>	6-7 km <sup>2</sup>	22km <sup>2</sup> (2003)	34.5 km <sup>2</sup>	8 km <sup>2</sup>
<b>% of Urban Area</b>	1.0%	1.4%	9%	0.4%

**Table 19 – Conditions for residents and business inside the charging zone.**

London and Stockholm reported little impact on businesses from the scheme, and the economy inside the charging zone followed general economic trends. Singapore did not have any significant impact initially as the scheme was only in operation during morning hours. However, when the charging time was extended to including evening hours, sales in some particular stores declined.

By using the same equation (Used in section “Scheme design”) Schemed Area/Urban Area, this indicates the share of urban residents that were living inside the zone, thus, the share of urban residents that were likely to benefit from the environmental improvements. Of the results, Stockholm had the largest share (9%) while the others were all below 1.4%.

## 5.5 Implementation process

	Singapore	London	Stockholm	Milan
<b>Trial period</b>	No	No	Yes	Yes
<b>Referendum</b>	No	No	Yes	No
<b>Change in Support</b>	ND	Yes	Yes	ND
<b>Finance</b>	Local	Local and Central Government	Central government	Local, Regional, Central government

Table 20 – Facts regarding the implementation process.

As shown in Table 20, Singapore, Milan and London introduced congestion pricing without consulting the public directly. In London it was a part of the Mayor's manifesto in the elections. In Milan it was implemented on a trial. In Singapore and London, the public were consulted regarding scheme design and in December 2008 Municipality of Milan announced that a public consultation was to be carried out in Milan in 2009.

Stockholm had a different approach when comparing its implementation process to the other schemes. The trial in 2006 was a decision by the central government, followed by a public referendum in Stockholm after the trial period. A majority of the people in Stockholm city voted in favor for a continuation of the scheme.

Public attitudes changed significantly in London and Stockholm, when comparing before and after implementing charges (there is no data from Milan or Singapore).

Singapore was the only city to finance its own scheme alone. All other schemes were partly or completely financed by the central governments.

## 5.6 Auckland

When assessing the ARPES-predicted conditions for Auckland in 2016, the mode share for public transport is lower than for the other cities that have adopted congestion pricing. Car ownership today in Auckland is about the same as in Milan.

When comparing the five congestion pricing schemes assessed in the ARPES report, two schemes were identified as suitable to be further assessed. These were the Double cordon and the Area scheme. The forecasted reductions in traffic for morning hours were 36% for the Double cordon scheme and 40% for the Area scheme. These figures are similar to the actual reduction in Singapore that saw a reduction of 45% in morning hours (The predicted traffic reduction in Singapore was 25-30%).

The ARPES report assesses the morning hours 6.00am-10.00am. The initial scheme in Singapore operated between 7.30am-10.15am. The ARPES report assumes that by charging morning hours only, the effect would be the same or nearly as efficient in the evening peak. This was assumed in Singapore too.

In both Singapore and Auckland, bus was the only public transport mode available. Singapore saw an expansion of public transport fleet by a third. The same increase is predicted to be approximately 27% in Auckland.

Lastly, when comparing the share of cars affected (cars affected by the tolls divided by total car fleet) with the vehicles affected in Singapore 1975, the figures are 22% for the Double cordon scheme and 27% for the Area scheme while this figure was estimated to be 30% for cars in Singapore. As cars represent 86% of the vehicle fleet in Auckland the comparison is fairly reliable.

## 6 Discussion

### *6.1 Chapter 2 and 3*

Congestion pricing is the only measure that alone can manage congestion to an optimal level for a given time and place. An optimal flow could be achieved with other measures. However, these would be more costly as they only partly address the congestion problem. Thus, the main argument for using congestion pricing is efficiency as well as it is cheaper than other measures.

The fact that congestion is one of the least wanted measures is probably the reason for why other (less efficient) measures have been adopted instead. As these have proven to be inefficient, congestion pricing has remained as the one of the last measure to introduce.

There is little doubt that congestion pricing is more efficient than most other measures to reduce congestion. However, one argument for not using congestion pricing as a measure would be if the road users do not identify congestion as a problem. On the other hand, congestion pricing should not be rejected just because more than 50% oppose the idea. There are different road users with different time values. Emergency vehicles and commercial vehicles have probably higher time values than other vehicles. Even though these represent a small group of all road users, their time loss will at the end be reflected in higher costs in other sectors; costs that the all road users are likely to face. Thus, if these groups identify congestion as a problem, this could be enough to implement the measure.

The problem could be compared to free downloading of music on internet. There is a high number of individuals that benefit from downloading free music, while those harmed (the musicians) represent a small group, stating that a general referendum would probably reject the idea about reimbursing the musicians if every individual only consider their own interests. On the other hand, many would probably agree with the idea that musicians should get paid for their music. Thus, implementing a new law without asking the public directly would likely be accepted with the time (under the assumption that enforcement is working). In the same way, congestion pricing in Stockholm and London have seen an increase of support after the introduction of the schemes as these have been accepted by more people.

Other reasons for not introducing congestion pricing could be a general reduction in car use due to an economic decline. Other factors affecting the car use can be a change of price in car related markets such as a change in oil price or steel or that a government increases the purchase tax or fuel tax. However, as mentioned before, if this happens, the market is likely to respond with cheaper and more fuel efficient cars.

## **6.2 Case Studies**

### **6.2.1 Conditions**

When assessing the conditions in the cities, Stockholm and London show similar conditions in terms of low car ownership and high modal shares for public transport in the morning hours. Singapore and Milan indicate low usage of public transport in the morning hours before implementing the scheme. This states that Stockholm and London were likely to require a smaller expansion in public transport than the other two cities. The high car ownership and density indicate that Milan was likely to suffer more from congestion than the other cities. In addition, as the vehicle ownership was high in Milan, this means that many people could afford a vehicle. This in combination of a low share of public transport indicates that those tolled off by a possible charge would mainly be low income earners, thus, the impact on equity was likely to be larger than for the other cities.

### **6.2.2 Scheme Design**

Stockholm implemented the most advanced system with a charge depending on both time and passage while the other three cities implemented a day ticket system. As there is no difference for vehicle type or location, there is no guarantee for reducing congestion or achieving a system optimum inside the zone. The other cities implemented schemes with a one day fee. Even though, they don't take into account, type of vehicle, time of day or location, the schemes can be considered user friendly when implemented, which is one of the criteria suggested by Jones (1998). In addition, the risk of implementing these schemes is lower. As the users become familiar to it, it is possible to further develop the scheme. Today, Singapore has the most advanced scheme with a charge depending on passenger car unit, time of day and to some extent on place. Thus, Singapore has got the system most likely to achieve a system optimum. The approach has been according to Emmerink (1998) starting off with a low tech scheme and developed further. It is likely that the other schemes will be developed in the same way.

All schemes used other measures e.g. increased public transport prior to or parallel to congestion pricing. This is necessary in order to meet the new demands and to make the passengers already on public transport ("the tolled on") better off.

All schemes had congestion as at least one objective. As well, environmental targets are part of the objectives in Milan and Stockholm. This is clearer in Milan where the level of charge depended on the pollution class of the vehicle. Thus, the scheme penalizes the polluters rather than the contributors to congestion. In Stockholm, it appears that the scheme is firstly designed to reduce congestion even though there are environmental objectives. The environmental objectives may be set in order to stress that there are environmental benefits as well. However, some vehicle classes were exempted the fee if classified as environmental friendly. An environmental objective is easier to achieve as the

benefits are directly correlated with the traffic reduction and the price (This is not clear with congestion as it may vary with time, space and changes in transport supply). Besides, an environmental objective is probably easier to understand and to be accepted by the public. Thus, a broader support among environmental groups or city dwellers can be achieved.

Looking at the equations “Scheme Area”/”Urban Area” and “Affected cars”/”Urban car fleet” the former share was significantly higher in Stockholm, while the latter was significantly higher in Singapore (30%) and Stockholm (20%) than the other cities (7-8%). The share of affected cars in Singapore is high when considering that the scheme operated only for 2.5 hours in morning time and the fact that the city had a high share of cars in the morning time.

All schemes had free alternatives or exemptions for those residents living outside the charging zone that were” forced” to drive through it. Milan and Singapore had higher number of exemptions for commuters than Stockholm and London. These were necessary measures as both cities had a low usage of public transport before commencing the charging schemes. The number of commuters likely to benefit from the scheme counted for 52% of all commuters (including pedestrians) in Singapore. Similarly in Milan, the drivers subject to pay the toll counted for less than 50%.

### **6.2.3 Demand response**

Traffic and congestion was reduced in all cities, showing that the scheme worked despite being relatively simple and not considering that congestion may vary within the zones, in time or that vehicles contribute differently to congestion. The traffic reduction was larger in Singapore, Stockholm and Milan than was predicted while being at the higher edge of the target range in London. There are several causes behind this. In Singapore this was related to a too high charge. In Stockholm and London the traffic flow was more sensitive to the charge for the hours outside the morning hours. In addition, the traffic was larger for the first months in Stockholm. Milan also saw large variations during the first year.

### **6.2.4 Traffic diversion**

#### **In time**

The traffic reductions in London and Stockholm were lower during the morning peak hours. This is likely reflected by the fact that a high number morning trips are work related, thus, less flexible in terms of changing time. In addition, the effect in the morning might encounter Downs’ law, stating that released road space attracts traffic from other times and perhaps other transport modes and roads. Milan shows a different pattern where the highest reduction can be seen for the morning hours. This data represent only one month and should be interpreted carefully. However, possible reasons could be that a higher share of the morning trips was not work related when compared to Stockholm and London.

Stockholm and London saw the largest reduction between peak hours. The fact that it occurred in Stockholm despite that tolls were only half of the charge in peak hours, reflect the difficulty of predicting the demand response. Furthermore, Eliasson et al. (2008) claim that the problem is partly due to the fact that those entering the city during low the peak, were still facing the higher charge on the way back. One possible way to address this problem could be by charging less in evening hours or, overall, outside the morning peak as the demand response appears more sensitive. On the other hand, the fee should not necessarily be free after the morning hours as this might attract through traffic, similar to what occurred in Singapore.

### **In place**

Traffic and congestion increased on the inner ring road surrounding the charging zone in Singapore. Even though this increase was related to a too high charge, it raised the awareness for the other cities, that road charges could divert traffic to other places. Thus, both London and Stockholm carried out traffic management prior to the commencement of the schemes and saw small immediate impact on the respective by passes. Even if congestion increases on a bypass or ring road it is not necessarily a deterioration, as these roads may be better suited to carry high levels of traffic than the inner city area. There is no information regarding Milan, however, facts indicate that there were no major impacts on the road surrounding the charging zone than for London. However, it is difficult to interpret the impact, as there no data for the traffic conditions on the road.

### **6.2.5 Public Transport**

Singapore did initially not see any improvements in bus times or speeds. London and Stockholm saw improvements in bus speeds and punctuality. Remembering Hau (1994) claiming that the people already on public transport (“the tolled on”) are likely to be worse off without seeing any redistribution of revenue to this group such as increased capacity of public transport. A capacity increase both affects the travel time as less people need to get on or off and it reduces crowding. In addition, more and new routes offer more flexibility for the passengers. These are probable explanations of why the passengers on new routes in Stockholm were more satisfied than passengers overall on public transport.

However, a major expansion of buses might cause problems such as congestion at bus stops and require substantially traffic management. Singapore saw an expansion by a third which is far higher than both Stockholm and London. Besides, Singapore did not have any commuter trains or metro making its transport more sensitive than both London and Stockholm. Despite these “bad” conditions, bus passengers perceived themselves as better off in Singapore stating that travel time is not the only factor affecting the attitude among the passengers.

When looking at customer satisfaction overall, it should be stressed that other factors not related to congestion pricing that might affect the result. Remembering that Hau(1994) states that most drivers

tolled off to other modes of transport or times are worse off as these are forced to change their travel behavior and that these would already be on public transport unless car was their preferred mode of transport. If this part counts for a large share of the people on public transport it, may affect the results too, as this group may compare its situation to commuting by car.

In Milan, average speeds and capacity for buses and trams were increased stating that commuters already on public transport were likely better off. On the other hand, the metro has seen an increase of 7.3% when comparing the whole period to the reference period (October-November, 2007). When comparing October –November in 2008 to the same months in 2007 the increase was 18% which could indicate an increase of crowding on the metro. However, there is no data available regarding this.

### **6.2.6 Adjustments and changes**

Singapore has changed and adapted its scheme significantly followed by unexpected demand responses. Even though there are lessons that could be learnt for the other cities when implementing their schemes (e.g. all day schemes and variable charges in time, traffic management on bypasses/ring roads), Stockholm and London have both adapted in terms of charge or removal of exemptions. The same is likely to happen in Milan where the number of vehicles subject to a charge are gradually decreasing and partly replaced by vehicles free from charge. Thus, the city needs to remove certain exemptions soon in order to maintain the level of traffic reduction above the objective of 10%. Since only 20-25% of the entering vehicles were subject to a charge in Milan, an effect similar to Downs' law could happen, where the released road space attracts new drivers into the charging zone.

Other possible adjustment in the future for the cities may be either tolling by-passing roads or roads going to the charged area if traffic increase on these roads. This may be a solution in Stockholm where the north south bypass has seen a significant growth in traffic. Lastly, all schemes will probably face higher charges for the charging zones affected by inflation and higher traffic demand.

A problem not mentioned in the analysis is the increased congestion seen in London in recent years, even though the kilometers driven within the zone has remained at the same levels since 2003. The reason given by Transport for London is that traffic speeds overall has decreased with the change of supply i.e. redistribution of roads to pedestrians and public transport. However, as well public transport has seen a negative trend in average speeds in the city since 2004. Possible reasons may be that public transport is adversely affected by the negative trend overall for traffic. Other reasons may be that the charge in London does not vary by location or time. Another explanation may be the fact that the peak in morning time is narrowed but still at a very high level that coincides with the many bus commuters during this time. Overall, this problem may be related more to the redistribution of road space rather than the congestion charge itself. On the other hand, this illustrates the redistribution of road space is more complicated than is assumed by Goodwin (1994), see chapter, 3.3.5 Policy.

Overall, it should be stressed that the level of congestion and traffic should not be compared to pre charging years in the long term, as the traffic demand overall changes with the time. The adequate comparison is to compare how the situation would be without congestion pricing for the same time. However, this comparison can never be done unless removing the scheme which may happen in London in 2010.

### **6.2.7 Economic and equity impact**

The cities have seen little adverse impact on business located inside the charging areas. Overall they have followed economic trends in general. The fact that all schemes are designed to end after working hours, means that shoppers can still enter the city for free at night. None of the schemes in London, Stockholm and Singapore (today) is in force later than 6.30pm. As well, shops can adjust their opening hours to suit the scheme times better. Another important factor is the initial mode share i.e. how many of the shoppers that used cars for this purpose. If the car share was low it will impact the business less.

#### **Residents**

Stockholm had the scheme containing the largest share of the urban area (9%) with 22% of its urban population living inside the charging zone. The other scheme areas had shares between 0.4-1.4percent. There is no data available regarding the number of residents living inside the charging zones, but the residents do most likely not represent more than 5% even when considering higher density in the central areas. Thus, Stockholm had the highest share of urban residents benefiting from the environmental improvements. As these were the group most positive to the scheme, this factor probably contributed to gaining a high support by the public when voting for the scheme.

Regarding the residents living inside the zone, London had the highest discount (90%) followed by Milan where an annual fee is equal to 25 daily entries, a theoretical discount up to 90% under the assumption of 250 working days a year. For Stockholm and Singapore, any vehicle can drive within the zone for free but have to pay when leaving the zone. Despite the absence of discounts for Stockholm and Singapore, the residents in Stockholm had the highest degree of support and the residents in Singapore perceived themselves a better off.

#### **Commuters**

Public Transport: Looking at initial conditions, London and Stockholm had high mode shares of public transport and low shares of cars in the morning peak. This indicate that owning a car was expensive already before commencing the charging schemes, and a majority of the commuters (including low income earners) were likely to be better off, under the assumption of an expansion of the public transport. In Milan and Singapore both cities had low shares of public transport commuting initially and its users were likely to be worse off unless seeing major expansions in the public transport fleet (In fact, the fleet was expanded by 33% in Singapore).

The results from the cities indicate that in all cities public transport commuters were on average better off or the same in terms of increased bus speeds, reliability and flexibility.

Drivers tolled and tolled off: In London, Singapore and Stockholm the drivers were on average worse off, including the tolled and tolled off. However, in Stockholm and London these represented a small share of the commuters. Conversely, in Singapore, the drivers represented a high share of the commuters. In addition, Singapore had the highest share of drivers tolled off which is partly explained by the fact that the original target was exceeded by 50-80%. Milan was the only city where the drivers on average were likely to be better off as only 42% of the entering traffic was subject to a charge and about 17% were tolled off.

In terms of equity impact in Singapore, the impact on different income groups was overall the same despite the high initial share of cars. In Milan, it is unclear if low income earners were affected to a higher extent than other groups, as the charge varied with pollution class. There is no data regarding this but the question is of major interest as 56% of those subject to a charge were tolled off. Further, Milan and Singapore provided more exemptions than London and Stockholm which were necessary measures in order to reduce equity impact among the road users as these cities had high a car usage. In Stockholm, drivers tolled off were mainly middle income earners. There is no data for this from London, but given the similar conditions to Stockholm, most low income earners were probably already on public transport before commencing the scheme.

What complicates interpreting the results is that swapping to another time, mode or road can also be interpreted as “not forcing the drivers to pay the toll” and that a good alternative is provided. Thus, if a low share of low income earners swapped, this could mean that there was no adequate alternatives or perhaps that these had less flexible starting times at work than other income groups. Thus, it is unclear on what basis the FHWA (2008) claims that low income earners in Singapore were not more affected than other income groups. On the other hand, there is no evidence that they actually were affected more than other groups.

In conclusion, there is no evidence that non car commuters were negatively affected of the congestion pricing schemes apart from Singapore initially. Moreover, in all cities the commuters benefiting from the schemes represented over 50% (when including pedestrians in Singapore) There is no clear evidence that low income takers were adversely affected more than other groups and there is no sign of general adverse impact on business or residents inside the zones. Thus, there is overall no evidence for the concerns regarding this expressed in section 3.3.3. In fact, residents inside the charging zones in Singapore, London and Stockholm were most positive about the schemes. As well, low income earners were probably better off in London and Stockholm as a result of the charging schemes and the improved public transport.

### 6.2.8 Implementation Process

Experiences from the cities show that there are different ways of implementing congestion pricing. In Milan and Stockholm they began as trials. Stockholm is the only city that has voted directly in favor for a congestion pricing scheme. One explanation for the different approach in Stockholm might be the large scale of impact on both residents and drivers. The share of the scheme area divided by the urban area was significantly higher than the other schemes. As well, the share of affected drivers was higher than Singapore and London.

In London, congestion pricing was a part of the mayor's manifesto for the elections. Thus, people voted indirectly for congestion pricing in London. In Milan, it is uncertain if it was a promise by the mayor in the elections but the scheme was firstly implemented as a trial. As the city had implemented similar schemes before the step to implement congestion pricing might have been easier as the public of Milan were more familiar with these kinds of measures. In Singapore, it was a decision by the government only. However, the city has had the same government since 1959. Thus, it was probably easier to implement congestion pricing in Singapore.

Singapore and London have carried out public attitude surveys and adjusted their schemes according to the findings from the attitudes. The Milan Council announced one year after the trial that public consultations would be carried out in 2009.

Regarding public attitudes, the public in Singapore reacted positively to the package of measures implemented. Stockholm and London show that attitudes tend to become more positive to congestion pricing after it has been implemented. This was important especially in Stockholm where the trial was to be followed by a public referendum. Experiences from Norway show similar progress in public attitudes before 1 year and after 1 year of road charging. In the three Norwegian cities first to introduce revenue charging schemes the negative attitudes in changed in Bergen, Oslo and Trondheim by (54%-37%), (70%-64%) and (72%-48%). (Odebeck, 2001). Manchester and Edinburgh held referendums or public consultations prior to a possible implementation. The proposals were rejected in both cities (in Manchester by 79% and in Edinburgh by 75%). (Homepage of The Guardian, 2005 and 2008). Thus, a referendum regarding congestion pricing will most likely not get any support if held before a possible trial.

Even though attitudes can change during a scheme the Western Extension experience in London shows how important it is to have a political consensus when implementing a scheme. However, there is yet another year to make improvements in the zone and the support might change the point of view of the mayor in the same way it changed the opinion of the new government in Stockholm in 2006.

There is little said about public attitudes of congestion pricing in Milan. However, the New York Sun (2008, (URL)) reports that the city was evenly divided at the time of the implementation. This was similar in London too, before commencing the trial. These facts state that the support in Milan was fairly high at the time of implementation despite that the conditions were "worse" than for

London. Reasons may be that the city implemented a scheme with clear environmental objectives that penalized only a small share of the road users and that the pollution issue has been known about the public for long.

In all cities, other measures were used than congestion pricing to manage congestion. This is probably a way of both increasing the efficiency of congestion pricing and gaining a higher support among the public. Furthermore, only Singapore financed its own scheme as the local government is as well the national government. All other schemes were either financed entirely or partly by the central government. This probably helps reducing possible financial concerns raised by the local public.

### **6.3 Overall**

Following the discussion, Stockholm and London had the best conditions for implementing a congestion pricing scheme. The high initial mode shares for public transport and low car ownership indicate:

- Impacted drivers represented a small share of the commuters in the morning peak
- Majority of commuters likely to benefit or be the same following the introduction of charges
- Low income earners were already on public transport before commencing the scheme.
- A minor and less risky expansion of public transport required.

Stockholm had a large share of residents living inside the zone that also had the highest support in the city. Further, Stockholm had two environmental objectives which are probably beneficial in order to gain a broader support as these objectives are easier to perceive by the public. These were important factors in order to gain support for the schemes.

When reading the reports about Stockholm and London, the reports issued by Transport for London focus more on traffic inside the zone while this is only one of four objectives in Stockholm. As traffic congestion in an area may depend on several factors, the outcome is more unpredictable than for instance inbound roads to the city. As congestion in recent years has increased in the original charging zone in London it is also more sensitive to criticism than if the similar scenario happened in Stockholm.

Stockholm is today a scheme designed to reduce congestion with both congestion and environmental objectives and with revenue used to road improvements. Milan is designed to reduce pollution but has both congestion and revenue as objectives.

Singapore saw the most radical implementation of congestion pricing in terms of a high price and a low initial PT/Car ratio, leading to a much higher modal swap than for the other cities. Singapore that was the first city to implement congestion pricing was aware of the congestion issue already in

the seventies. Even though the literature describes the people of Singapore as law obedient and as highly accepting of new laws it is clear that Singapore needed demand measures in order to control congestion as Singapore was becoming one of the densest countries in the world. This probably contributed to convince the people too.

Milan had the smoothest implementation process by affecting the lowest amount of road users. In addition, it was the only city offering multi entrance discounts. Even if the charge becomes cheaper, the high car ownership ratio of Milan indicates that even a small charge can have a significant effect. Secondly, high car ownership ratio indicates that low income earners are likely to be tolled off and that supply of public transport might be poor. The discounts provided and a scheme designed to toll a low share of drivers is an approach suitable for cities with high car usage. Despite the low number of tolled drivers, the traffic reduction in Milan was nearly as high as in London. Milan and Singapore had similar conditions and provided more exemptions than the other cities and their experiences are interesting for other cities with high mode shares for cars, planning to implement road pricing.

The examples of the four cities illustrate that there are several approaches of designing a scheme. Overall, the scheme design depends on the initial conditions of the city and as well the acceptability by the public. The experiences from the cities show that congestion pricing is a viable measure as both congestion and traffic were reduced by using a measure that is relatively cheap when compared to possible capacity measures. In addition, the experiences show that concerns from the public can be addressed with an appropriate scheme design and other measures used parallel to congestion pricing.

#### ***6.4 Auckland***

Auckland has the lowest mode share of public transport when compared to the other four cities earlier discussed. Mode shares do not give an accurate comparison between cities as these depend on which areas of the city are included. However, the figure for Auckland is still most likely the lowest of the assessed cities. In addition, car ownership is high. These facts state that a high number of the road users are likely to be worse off if introducing a congestion scheme, and that a high share is low income earners.

The scheme design of the Double cordon and the Area scheme had several features in common with the initial scheme in Singapore. These were:

- A high number of the cars were affected and predicted to be tolled off
- Schemes were operating in morning hours only, assumed to reduce congestion in evening hours as well.
- A high increase of public transport required.
- The affected drivers represented a significant amount of the total car commuters

Singapore implemented a scheme with the highest impact on traffic of all cities. There are several authors that claim that the toll was too high in Singapore and that this explains the problems with traffic diversion outside the charging area. As the predicted reductions are similar to the actual reductions in Singapore, it could be claimed that the tolls are too high in Auckland as well. However, the primary intention of the toll is likely to reduce traffic overall in Auckland rather than achieving an optimal flow inside the charging zone.

In the ARPES report (2005b) it is assumed that by charging mornings hours only, the traffic reduction would be the same or nearly as high in the evening peak time. The first scheme in Singapore was implemented with the same assumption. However, traffic in the evening remained at the same levels as before implementing the scheme. Therefore, the assumption in the ARPES report is questionable. The charging time covers a longer time of the morning period in Auckland (6.00-10.00am) than in Singapore (7.30 - 9.30am (extended to 10.15am after one month) and the traffic diversion in time is probably lower than in Singapore. However, the traffic diversion in place in Auckland is of higher risk, especially for the smaller area scheme, when considering the high predicted traffic reductions.

The predicted increase in public transport is similar to Singapore, and requires major investments in new buses and infrastructure to provide for a free alternative for those not wishing to pay the fee.

A referendum or public consultations may be held prior to any implementation of a scheme, as this is required for tolled roads according to the Land Transport Management 2003. Another reason is that the scheme affects a high amount of the total commuters in Auckland, about the same as in Stockholm, where referendum was held (however, this was held after the implementation)

There is a high degree of concern regarding congestion in Auckland. However, the public transport usage is low and according to the submissions analysis carried out in 2007 the opposition was high. The opposition is likely to be reduced with further improvements in public transport and with the completion of the western ring route that would provide for a free alternative, if a scheme would be proposed. However, even in cities as Stockholm and London the support was less than 40% before the implementation of the congestion schemes, even though both cities had a high degree of public transport users and free alternative ring routes.

Moreover, even though Singapore could implement a similar scheme to the ones assessed in Auckland, the literature stresses that Singapore is seen as an exception as the government has extensive powers and the people are described as very law obedient. This may explain why such an implementation was possible to carry out. Furthermore, even though Milan and Singapore both had a low public transport usage, the schemes were, in both cities, introduced without public consultations. Thus, congestion pricing will most likely be difficult to implement in Auckland, if a public consultation is required prior to the decision. However, the attitude survey carried out in the ARPES report in 2006b, unlike the submissions analysis, showed a more even result of

support/opposition to a congestion scheme, once again showing that consultations are likely to show a different result than attitude surveys.

Below are recommendations given for two possible schemes, one with congestion as a principal objective, the other with revenue:

#### **6.4.1 Congestion Pricing Scheme**

A congestion scheme would require several measures in order to address equity issues especially among car users. Car pools could be exempted the fee and certain vehicle classes e.g. environmentally friendly cars and multiple entrance discounts could be provided (similar to Milan). Milan is the only city with a scheme that made the road users generally better off, by tolling the polluters that represented only 42% of the entering traffic. This could be interesting for Auckland as well, but may require reducing pollution to be an objective. On the other hand, this objective is likely easier to perceive by the public than reducing congestion. Another option that might increase the public support for congestion pricing is to redistribute all or part of the money received by the authorities, back to the drivers through reductions in annual vehicle tax. This measure was once suggested by the authorities in Hong Kong in the 1980s (Button, 1998). This would probably make most drivers better off. On the other hand, as vehicle taxes in New Zealand are all earmarked to a road fund used for investments and maintenance in road infrastructure, this measure would probably be disputed. If other taxes are possible to reduce is difficult to say. From a socioeconomic point of view this measure would still require investments in public transport and money allocated from other sectors. On the other hand, the investment in public transport would likely be cheaper in the long run than expanding the road capacity for car demand in peak time. Below follows a few recommendations for Auckland:

- A whole day charge covering both peak hours and the time in between (unless the intention is to reduce congestion in morning hours only). The charge may be lower for hours outside the morning peak.
- It is important to point out that there are environmental benefits in terms of reduced traffic as this effect is often easier to understand by the public. If a better environment is set as one of the objectives, it is possible to gain more support from residents living within the charging zone as well as environmental groups.
- Complete the Western Ring Route before commencing any scheme, to provide a free alternative for those not wishing to access the city. If not completed, main roads through the zone need to be free from charge.
- Implementing any of the schemes identified would require a major expansion in public transport. To minimize any risk it is important to increase the fleet before the introduction of any scheme.

- Equity issues are important as the low usage of public transport and high car ownership indicate that many people can afford a car and a charge levied would mainly affect the low income earners first. These conditions are most similar to Milan and there are and will likely be lessons learnt that can be used for Auckland e.g. multiple entrance discounts, charging by pollution class etc. Exemptions for car pools should be used.

#### **6.4.2 Revenue scheme**

There is no information available regarding size and place for the revenue schemes. Therefore, only broad comparisons to the congestion schemes can be made:

A pure revenue scheme (with congestion as a secondary objective) is likely to gain a higher support in Auckland as this objective would be clearer to the public. A revenue scheme was implemented in Oslo in 1990. The traffic was estimated to have reduced by 5% as an effect of the scheme even though it was designed to have minimal impact on traffic (Johansson & Mattsson, 1994). Under the assumption that traffic is reduced by 5% of one of the schemes in Auckland, this could still have significant impact on the use of public transport (considering the low public transport share). With further improvements in the public transport system the scheme could change to reducing congestion as the main objective in the future. Equity would be of less concern compared to congestion pricing. However, the tolled off would still be low income earners. The scheme would have little impact on traffic and congestion and may not require the completion of the Western Ring Route or increase in public transport to the same extent as any of the congestion schemes. Thus, a revenue scheme could commence at an earlier stage than a congestion scheme. Revenues can still be used for improvements in transport infrastructure including public transport projects.

## 7 Conclusions

### 7.1 Chapter 2 and 3

Congestion is a phenomenon associated with:

- Rapid growth in car ownership and car usage at the expense of public transport
- The fact that cars contribute to congestion more than public transport
- A problem in the big cities due to
  - Lack of space
  - Recurrent travelling in morning and afternoon
  - Rapid growth in population or economic activity

Supply side measures are expensive in urban areas as these often require complex solutions. As well, they tend to encounter Down's law stating that new road space will attract drivers from other roads, other times and other modes of transport in peak hour. Thus, supply side measures cannot manage congestion alone. Of the possible demand side measures, congestion pricing is the only measure that can directly manage congestion when and where it occurs. Other measures only affect congestion indirectly and would have to be more expensive in order to achieve the same effects as congestion pricing.

Congestion pricing makes all road users generally worse off. Those paying a toll will gain a small increase of speeds. Those swapping to other roads, times or modes of transport are forced to change their travel behavior and those on public transport are likely to face more crowding when more people use public transport. However, if the revenue collected is distributed back to the road users more will benefit from congestion pricing. Thus, the revenue distribution is of high importance in order to implement a successful scheme.

There are other concerns regarding congestion pricing:

- Traffic diversion due to the tolls imposed, may cause congestion in other areas
- The tolls may hit low income groups harder than other
- Residents inside the area may be forced to pay the toll
- Business inside may be adversely affected if less people travel to the charging zone

These are reasons why congestion pricing is difficult to implement and there are today more proposals that have been rejected than accepted. On the other hand, as more cities become aware that other measures are inefficient, congestion pricing is likely to be more adopted to a higher extent.

### 7.2 Case Studies, analysis and discussion

The cities that have implemented congestion pricing are Singapore (1975), London (2003) and Stockholm (2006 on Trial, 2007 permanent). In 2008, Milan implemented on trial a scheme designed

to primarily reduce pollution. The city was included in the case studies as one of the objectives was to reduce traffic.

Considering the initial conditions in the city, Stockholm and London had high shares of public transport usage and low car ownership when compared to the other cities. These facts indicate that only a low share of the commuters would be subject to a charge a higher amount to benefit from the scheme. As these were lower in Singapore and Milan, these cities had more exemptions and discounts than the London and Stockholm to reduce the impact on the road users.

All cities but Stockholm (with a variable charge during the day) had initially a one day fee for entering the charging area. No city charged vehicles according to their contribution to congestion. Public transport was exempted the fee in all cities. Singapore and Milan had more discounts than London and Stockholm.

All cities reduced traffic and congestion inside the charging zones. Singapore was the only city to experience congestion outside the zone initially. These experiences show that congestion can be managed with a relatively simple system despite that the charge did not vary by time (Exception: Stockholm), place within the charging zone or by vehicle.

All cities expanded public transport. London and Stockholm saw generally improvements in terms of speeds and punctuality. The speeds increased in Singapore inside the zone but decreased outside due to higher traffic. In Milan, speeds increased inside the charging zone.

Regarding traffic outside the zone, Singapore initially experienced higher traffic congestion while this remained at the same levels in Stockholm and London. There is no data for this in Milan. Regarding traffic reduction in time, for Stockholm and London, the largest reduction could be seen outside the morning peak, stating that the charge possibly could be lower for those hours. There are signs for this in Milan too, but the pattern has varied more throughout the year.

Considering changes and adjustments, all schemes but Milan have adjusted their schemes with the time. These have generally been removal of discounts or increasing the charges. These are necessary changes as the traffic demand has increased and is likely happen as well in Milan. Experiences in Singapore and Stockholm show that road users have responded to incentives to a higher extent than was predicted by the transport authorities.

There is no evidence that low income takers were affected more than other income groups in Singapore, London and Stockholm. In fact, these were likely better off or the same in London and Stockholm as these were already on public transport prior to the schemes. There is no information regarding this in Milan. Milan is the only city where drivers generally were better off as less than 50% were subject to the charge.

Residents within the zones in Singapore, London and Stockholm responded positively to the introduction of the schemes. In London and Stockholm these were the most positive groups in the city.

In Singapore, London and Stockholm business have followed the overall economic trends of the city or country. There is no information for Milan as the scheme is relatively new.

Regarding the implementation London, Milan and Stockholm had schemes partly or entirely financed by the central governments. This fact likely made the financial issue of a smaller matter in the cities. No city arranged a referendum prior to the implementation and the overall experience shows that congestion pricing is likely to be rejected if doing so. In Stockholm and London the public support increased significantly after the implementation. There is no data regarding this in Singapore and Milan. Milan and Stockholm had environmental and revenue objectives. As these are likely easier to perceive by the public, the public support of the scheme is likely to increase.

Overall, the cities show that congestion or environmental pricing is a viable measure to manage traffic and congestion. Furthermore, the concerns about the potential negative impacts, overall, have not occurred, or have occurred to a small extent. Experience also shows that congestion or environmental schemes can be adapted after the conditions of the city i.e. a city with high car usage and a share of low public transport can have more discounts and exemptions.

Regarding a possible implementation in Auckland, there are currently five different proposals of congestion pricing schemes. Of these, two schemes were identified in this report as the most suitable schemes, a *Double cordon scheme* and an *Area scheme*.

The initial conditions were similar to Milan: Low use of public transport and high car ownership. The scheme design had several features in common with Singapore such as:

- Charging hours were for morning hours only, assumed to reduce congestion in evening hours as well.
- A high number of the cars affected, were predicted to be tolled off
- A high increase of public transport required.
- The affected drivers represented a significant amount of the total car commuters

One of the key findings from the assessed schemes was that Singapore implemented the scheme with the most radical effects. Even though commuters today are better off in Singapore, such an implementation requires a high compliance from the public. A similar scheme in Auckland is difficult to achieve, especially if a public consultation is required prior to any implementation. If it is possible to implement such a scheme, it is important to address equity issues and provide a free alternatives such as adequate public transport and a free bypass (for those not wishing to enter the charging area). Furthermore, traffic in Singapore was not reduced outside the charging hours. Thus, if the intension is to reduce traffic outside morning hours, the scheme should operate during those hours too.

The transport authority in New Zealand is also considering a road pricing scheme with revenue as the first objective. This option is likely to get higher support from the public as this objective is easier to perceive than congestion. As the mode share is low for public transport in Auckland, even a small reduction in car use could increase public transport use significantly. Furthermore, as the traffic impact would be low, less preparation would be required and a revenue scheme could thereby commence before any of the congestion schemes.

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## Appendix A – Definitions

### *Economic definitions*

Transport contains various economic characteristics that will be defined and discussed in this section.

### **Public and Private goods**

A good can be divided into four different categories depending on if it's an excludable or a non-excludable good and a rival or a non-rival good. The four categories are Private goods such as candy and a pencil. Common goods are goods that are difficult to exclude anyone from consuming e.g. it's difficult to exclude a person from fishing in a big ocean. However, when the fish is caught, no one else can consume it. Club goods, conversely, are goods that are possible to exclude somebody from using, but their usage will not obstruct anyone else from consuming the same good. An example of a possible Club Good is a cable TV. Goods that are both non-rivalrous and non-excludable are called Public Goods. These are generally goods that everyone can benefit from once they exist. However, the benefit for one person is generally lower than the total cost. If everyone would share the total cost the benefit may be higher than the cost per person. This is the reason why the goods usually are provided by the government. (Perloff, 1998)

	<b>Excludable</b>	<b>Non-Excludable</b>
<b>Rivalrous</b>	<b>Private Goods</b> Candy, Pencil, Toll Road with congestion	<b>Common Goods (Common-Pool Resources)</b> Fish and Hunting Road with congestion
<b>Non-Rivalrous</b>	<b>Club Goods</b> Cable TV , Concert Hall Toll road with no congestion	<b>Public Goods</b> Clean Air, national defense, Road with no congestion

*Table 21 - Private, Common, Club and Public Goods.*

As can be seen in Table 21, a road can be any of the four categories depending on if it is congested (rivalrous) and if it is excludable.

A non-excludable road can be excludable but to a certain cost which depends on its conditions such as the cost for toll collection and enforcement. Furthermore, the same road can be private and a common good as congestion may vary with the time.

Lastly, another feature that can make a road collective is the value to access it in case of an emergency. The value of the road when it needs to be used by emergency vehicles is very high in those moments. This “insurance” or “readiness” aspect makes the road classified as a public good. (Johansson & Mattsson, 1994, p.9)

Thereby a road can be categorized as a different type of good depending on its conditions.

### **Derived & Latent Demand**

In economic terms transport is normally defined as a derived demand. Some goods are not demanded for their own sake but in order to be used for the production of other goods and services. (Parkin, 1990) “The demand for those goods is derived from the demand for those commodities which the resources are capable of producing” (Tisdell, 1982, 24) Thus, the demand for steel is derived from the demand for commodities containing steel, or computers may be derived for secretarial services. (Thompson Jr, 1977)

Transport is a service which is rarely demanded for its own characteristics but derived from some other service. For example, a company may see transport as a means of moving its products from the warehouse to the retail store. As the demand for its products increases, so does the demand for transport. (Cole, 1998)

Private trips in urban regions are usually not carried out because of a desire but rather due to a need for traveling to places where other activities are carried out, e.g. work, school and shopping. (Bull, 2003, p.26)

Secondly, transport is discussed as being a latent demand (used interchangeably as induced demand in this report). This applies to a situation where a particular need has been recognized but no product or service has been offered to satisfy this need. (Gopal, 2007) The increase of production of one agent is done, therefore, to meet the increased demand of another agent. (OECD, 2007)

### **Externality**

Transport in general and particularly car usage gives rise to a number of external effects. The appearance/occasion of an externality is defined as follows:

“An external effect exists when an actor’s (the receptor’s) utility function contains a real variable whose actual value depends on the behavior of another actor (the supplier), who does not take these effects of his behavior into account in his decision making process.”

(Verhoef, 1994 *quoted in* Emmerink, 1998 p.36)

An external effect can either be negative or positive depending on how it affects another part, not considered by the producer. Transport, however, is generally associated with negative externalities such as pollution and congestion. (Button, 1993) Figure 28 illustrates an example of an external effect. The supplier of a good produces the quantity  $Q_p$ . In this point the marginal private costs (MPC) are the same as the marginal private benefit (MPB). If the supplier would produce over this level, the added benefit (MPB) would be less than the added costs (MPC) for the extra quantity produced. Thus, the supplier only produces the level of  $Q_p$ . However, the production causes a negative externality as well, suffered by the society. If these extra costs were considered by the producer, for instance by paying a tax (commonly called a Pigovian tax) equal to the difference between the marginal social and private costs, the firm's MPC would be equal to the MSC. Thus, the supplier would instead produce the quantity of  $Q_s$ , where the marginal social costs (MSC) are equal to the marginal private benefits (MPB). (Nicholson, 2002)

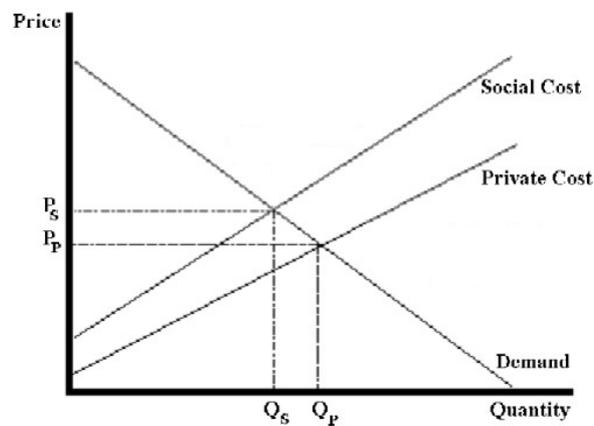


Figure 28 – A negative externality. (Wikipedia, 2008a)

Thereby, the Pigovian tax does not aim to eliminate the externality, but rather to find the “right” level of externality.

Moreover, externalities can be divided into two categories of externalities; pecuniary and technological externalities. The latter effects occur in the production or consumption, while the pecuniary affects a firm's costs due to changes in price affected by other firms' actions in selling and buying.

For example, a new road might cause effects on people living around it through noise and pollution. These effects affect the people directly and are therefore technological externalities. As well, the road might affect local business negatively by making clients prefer other areas. This is a pecuniary externality because of its indirect effect on prices in both areas affected by the new road. (Button, 1993)

## Investment Criterion and Pareto Efficiency

In order to make an investment decision a cost-benefit analysis (CBA) is a commonly used tool to assist the decision. All costs are usually quantified and so are the benefits. For example, the costs of road such as capital and operational costs might be measured against its benefits i.e. time reductions for travelers and less operational costs for the vehicle.

The idea with a CBA is to maximize social surplus. One major issue is the interpersonal comparisons of welfare, i.e. has social welfare risen if one group benefits at the expense of another? This is a common situation in road transport where the road users are the winners and the non-users suffer. To get around this the CBA adopt hypothetical compensation tests. (Button, 1993, p.179)

The most fundamental principle to rank different allocations of goods and services is the Pareto Principle for which no interpersonal comparisons need to be made. (Perloff, 1998)

Firstly, according to the Pareto Principle, any change where at least one person is better off and none suffers is socially desirable (Button, 1993, p.179). Secondly, an allocation of resources where it is not possible to make one person better off without worsening for everyone else, is said to be Pareto Efficient. (Nicholson, 2002)

However, most transport investment problems appear when an investment generates both costs and external costs on some members or groups of a community, thus, making the strict Pareto criterion of little use. Methods developed from this problem investigate instead the possibility of a redistribution that makes every part better off after an investment, thus, making it a *potential* Pareto improvement.

One approach is made by Kaldor (1939 *in* Button, 1993, p. 179) that states that an investment is socially desirable if the winners could compensate the losers and still remain better off. A similar approach was made by Hicks (1940 *in* Button, 1993, p.179) that looks from the losers' point of view: A scheme is socially desirable if the losers cannot bribe the winners not to do it without becoming worse off themselves. These, similar approaches are usually called *Kaldor-Hicks* or *potential* Pareto improvements. (Button , 1993, p. 178-180)

## First and Second best

Economic models are based on a number of assumptions. These assumptions lead to a logical solution that is referred to as equilibrium. The solution is also called optimum as economic models are based on the maximizing behavior of the producers and consumers.

Consider a small economy with perfect competition and where everyone has the same access to information, all goods are privately owned and there are no externalities produced. Consumers maximize their utility and firms maximize their profit, employment is zero etc. Under these

conditions the economic efficiency and the welfare is optimized and the prevailing equilibrium would be called first-best.

However, in the real world one or several of these assumptions are unlikely to be satisfied e.g. externalities, monopolistic firms or different information among the consumers. In the case of a monopolistic firm the price would not be set to equal the firm's marginal costs. In the small economy example the new obtained equilibrium in would be less efficient than the optimal, thus, called second-best equilibrium. Thereby, a second-best equilibrium is achieved when one or several conditions cannot be satisfied.

Furthermore, in the second-best situation the government can apply a policy such as taxes or subsidies in order to improve the economy. The optimal policy that raises the national level to its greatest extent in a particular situation is called a first-best policy. Any other policy that raises the welfare to a level below the optimal is called a second-best policy. (Suranovic, 2008, (URL))

## **Appendix B – Alternative Measures**

### **Flexi time**

According to Downs (2004) the traffic commuters in the USA in 1995 represented 47% of the traffic during the peak hours 6-9am and 4-9pm. Thus, mathematically an increase in people working outside those hours would have significant effect on the level of traffic. However, similarly to public transport the space freed up is likely to be taken up by other drivers according to the principle of triple convergence (drivers from other times, modes of transport or other roads). Thus, the effect on traffic is limited. (Downs, 2004)

### **Land use planning**

Transport is in most cases a derived demand associated with the destination of traveling. Thus, transport and urban land-use are connected which means that the planning of land use affects the way and the amount of traveling. A compact city may generate a lower amount of travel than a spacious city. As well, the location of activities can affect the amount of travel. The problem with such an approach is that it is both a complex and a long term approach with uncertain outcomes and there are also limits such as historical part of cities that restraints the possibility of doing so. (Button, 1998)

One of few examples where land use planning has been successfully adopted is Curitiba, Brazil where high density houses have been built along five bus transit corridors working as an “above ground metro”. Even though the city increased from 150 000 in the 1950 to 1.6 million in 1995, today 80% of the daily commuting occurs on the on the ground metro. (Downs, 2004)

## **Appendix C – The Western Extension in London 2007**

On 19 February 2007, the charging zone in London was extended westwards, covering the Royal area of Kensington, Chelsea and parts of City of Westminster that were not included in the original scheme. All together, the new size of the levied area was nearly 40km<sup>2</sup>. As with the original scheme, the boundary route was free and another two routes: the part of the inner ring road from the original scheme (between the original and the extended area) and the A40 westway that was partly going through the western extension. As in the original scheme, residents living in the area were entitled a 90% discount. As well, a number of residents living just outside the charged area were subject to the discount. This, because some had their local services such as health care and parking inside the zone.

Even though there were many lessons learnt from the original congestion scheme, there were a few differences between the original charging zone and the new western extension that were likely to change the outcome. Firstly, there were 1.1 million work seats in the original zone while only 170 000 in the new area. Reversely, there were many more residents in the new area than in the original congestion zone. This would increase the number of 90% discounts significantly. This discount was valid for the original congestion zone too and likely to increase the traffic in the original zone. In addition, the share of retail, hotel and restaurants were 32% while in the original zone this figure was only 12 %. Thus, there was a concern that local businesses in the new area were more likely to be affected negatively of the congestion charge. (Santos & Fraser, 2006) Another difference was the difference in traffic entering the area. In 2002, the number of vehicles entering the original congestion zone was 378 000 (TfL, 2004) while for the extended area, the entering traffic for a day was 253 000 (TfL, 2007)

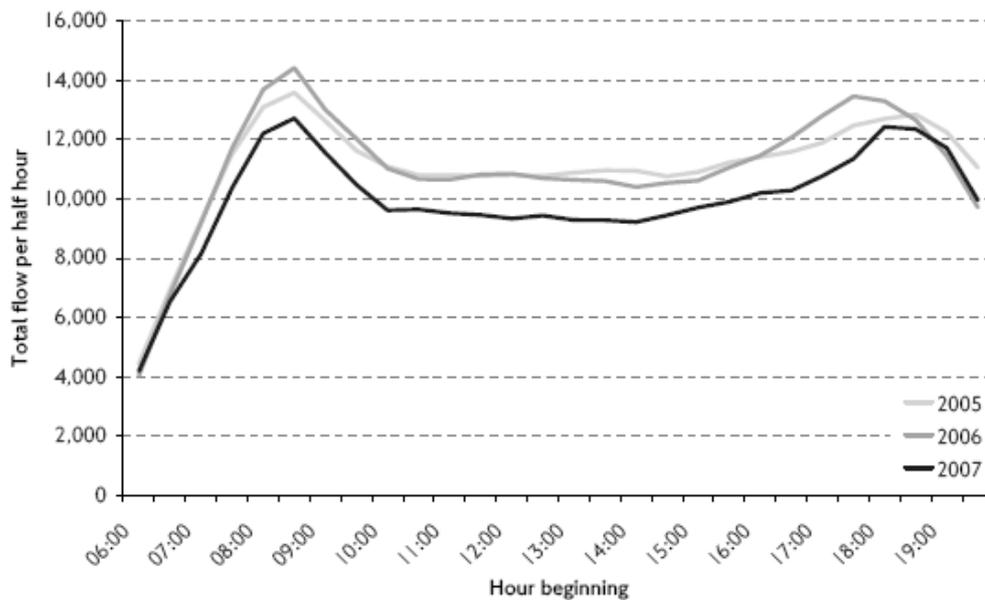
The traffic in the western zone was affected by the congestion charge in the original zone in earlier years. Entering vehicles on four or more wheels were reduced by a third for the years 2002-2006. (TfL, 2007) Despite this, the group “cars and minicabs” counted for 69% in 2006 in the western zone. For the original zone, this figure was 47% for the year before implementing the congestion charge.

Entering Traffic and Vehicle Kilometers Driven in the Western Extension Zone		
Mode of Transport	Entering	VKD
All Vehicles	-13%	-10%
Four or more wheels	-14%	-11%
Potentially Chargeable	-18%	-14%
Cars and minicabs	-22%	-18%
Vans	-8%	-2%
Lorries and Other	0%	1%
Non chargeable	3%	6%
Licensed Taxis	0%	4%
Buses and Coaches	0%	13%
Powered two Wheelers	8%	9%
Pedal Cycles	8%	4%

Table 22– Changes in traffic entering and vehicle kilometers driven (VKD) in the western extension for the years 2006-2007. (Adapted from TfL, 2008, table 2.1, p.20, table 2.3, p.25)

As can be seen in Table 22, the number of entering vehicles in the extended zone was reduced by 18% in 2007. Potentially chargeable vehicles were reduced by 18%, of which the number of entering cars was 22.5% lower than previous year. TfL predicted a reduction for cars between 22% and 28%. As well, a reduction between 13% and 17% of vehicles with four or more wheels and an increase for buses with 10-15% was predicted. The actual changes were -14% and 13% for these groups. (TfL, 2008)

Figure 2.2 Traffic entering the western extension zone by time of day. Annualised weekdays, 2005 to 2007, all vehicles.



**Figure 29** – *Traffic entering the Western Extension Zone for the years 2005-2007. (TfL, 2008, Figure 2.2, p.20)*

As can be seen in Figure 29, traffic flows were similar for entering traffic during a day. Traffic circulating within the extended zone went down by 10%. (TfL, 2008) Measured in absolute numbers, the reduction was relatively even for all charging hours. (Authors Remark)

In terms of congestion in the western extension zone, Traffic for London estimated the free flow travel time to be 1.8min/km while the average excess time was 1.75min/km based on 12 surveys in 2005-2006. The average excess time was 2.0min/km in 2003-2005, thus, had seen a reduction after the implementation of the original scheme (TfL, 2006). The average network speed was estimated to 17km/h. TfL estimated that congestion in the western zone would reduce by 17% to 24%. However, the actual reduction from several surveys taken in 2007 was only 3%. Transport for London (2008) claims that the measured excess time varied strongly during the year. (TfL, 2008)

The number of passengers on entering busses increased by 6% during charging hours (9% in the morning peak) in 2007. To meet this demand the network capacity was increased by 16%, thus, the average number of passengers was lower in 2007. Moreover, the average bus speed was unchanged in 2007 within the zone and the average waiting time for buses saw an increase of 6% while boundary and radial routes saw an increase of average speeds and improvement in reliability. (TfL, 2008)

For the free passage routes going between the original and the extended charging zone the traffic increased with 5% compared to the previous year while traffic on the other free route decreased by 6%. (TfL, 2008)

**Table 7.2** Attitudes to transport and the local environment, 2007/08.

		Worse	Better	Net positive
Air quality/the environment	Western extension users	10%	17%	7%
	London residents	4%	31%	27%
Personal safety on public transport	Western extension users	12%	11%	-1%
	London residents	-	-	-
Parking provision	Western extension users	14%	9%	-5%
	London residents	-	-	-
Bus service supply	Western extension users	8%	28%	20%
	London residents	3%	33%	30%
Bus journey times	Western extension users	10%	27%	17%
	London residents	4%	34%	30%
Underground provision	Western extension users	11%	9%	-2%
	London residents	-	-	-
Traffic congestion/ journey times	Western extension users	14%	32%	18%
	London residents	6%	26%	20%

**Table 23** – *Attitudes to transport and the local environment among London residents and "Western extension users". (TfL, 2008, Table 7.2, p.149)*

As can be seen in Table 23, the attitude survey showed that the western extension users were most positive about traffic congestion and bus services.

Regarding the economic impact, six to nine months after the commencement of the new zone, business reported weaker sales and tourism were lower. However, this compares with strong performances in 2006 and may be similar to overall trends in the wider economy. Since all necessary data to evaluate the economic impact was not available when the last report was released by Transport for London, it was too early to fully evaluate the economic impact from the new charging zone. (TfL, 2008)