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Master Thesis

Congestion Pricing in the Netherlands

A comparison of two road pricing systems

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Preface

This thesis concludes my Master's studies in Economics of Markets, Organisations and Policy at the Erasmus University Rotterdam. With this paper comes an end to my seven years of studying. The writing of this research has been a long, intensive and sometimes seemingly endless process. Now, at the end, I can honestly say it was all worth it. I have gathered new valuable insights that I will bear with me for the rest of my life. I would like to express my gratitude to a couple of people who have made it all possible.

First of all I would like to thank my supervisor, dr. Benoît Crutzen for many useful comments and ideas.

Second of all my gratitude goes out to my parents who have supported me, mentally and financially, for all those years.

Last but not least I would like to thank all my friends who have kept me focussed at times and relaxed at moments it was necessary. Especially Barbara, Joost, Marc and Mattis deserve some special attention. The extensive lunches and endless coffee-breaks with them were the highlights of my long days of study!

Abstract

In this paper I study the congestion in the Netherlands, specifically Rotterdam. Congestion is one of the biggest problems that economies are facing nowadays. Economic growth, along with the population growth, is one of the main causes of congestion. At the same time, this growth is under pressure because of congestion. Something has to be done.
In London there is a good working congestion pricing system, the London Congestion Charge. A closer look at this system learns that its success is mainly due to a positive public opinion and a reliable public transport system. The absence of these two make it very doubtful that a similar congestion charge could work in Rotterdam.
I therefore started to look for other possible solutions and came across the slot reservation system. The system is not yet implemented anywhere. This not only makes it hard to compare but this also brings some favourable and unfavourable features with it. I think Rotterdam and the Netherlands are not yet ready for the implementation of such a system.
A comparison of the two systems learns that the congestion charge is slightly better, mainly because of the applicability of an existing system compared to that of a new one. Overall can be concluded, that the Netherlands are not yet ready to implement a [new] congestion pricing system. As long as there is no shift in dogma, chances are that implementation will lead to failure.

KEYWORDS: *congestion pricing system, LCC, slot reservation, traffic, Rotterdam*

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1. Introduction

Everyday thousands of people are grounded in kilometres long traffic jams on Dutch highways. The loss in travel time due to this can have a huge impact on our economy. Although congestion affects a lot of people and is a worldwide problem, up to now there has not been one unique problem-solving solution.

That the congestion problem is a huge problem can also be seen in the fact that there is an increasingly large number of papers on the matter. Since the early nineties, the awareness has grown that traffic jams were not only inconvenient, but could lead to severe economic damage and losses. Traffic jams are a negative externality of economic activity and the mobility that enhances these activities. At the same time, congestion can cause serious delays leading to diminishing economic growth. The problem is two-sided. On the one hand the problem is created by economic growth; on the other hand it should be solved in order to keep the economic growth. Over the years there have been several proposed solutions to the problem. Economist and researchers differ in their opinions on what the right solution is. The only thing that they agree on is that to this day none of the solutions or measurements that have been taken is sufficient.

In this paper I will research the situation in the Netherlands, more specific in the Rotterdam area. Rotterdam, the second-largest city of our country, has some specific properties that make it useful to research. First of all the urban area of Rotterdam has some of the highest road usage in this country. Combined with a high percentage of road usage by the transport of goods, this gives rise to some interesting problems. The congestion on the ring of Rotterdam has a direct influence on its harbor, which is among the largest of the world. The Netherlands is known for its high import/export ratio. In order to stay competitive it is very important that transport of goods via our road network remains efficient (DVS, 2009).

Also, there has already been a lot of research on country wide solutions to the congestion problems. None of these have been proven effective. The fact that my research is bounded to a smaller area makes it unique. It also makes it better comparable with London, where there has been a successful implementation of a congestion pricing system.

In this paper I will propose two different solutions to the problem. My first solution is a kind of congestion charge, similarly to the ones in cities like London and Singapore. I will show if and why this could work for Rotterdam. The second solution is one that appears in some papers, but has never been implemented: a slot reservation system. The fact that one is new and not yet implemented makes it hard to compare the two, but I will try to do that anyway.

The rest of this paper is organized as follows. In the next section I will have a look on the theory and literature on this matter. After that I will shortly introduce the London congestion charge and compare it with the situation in Rotterdam. In this section I will introduce my model and show what the expected effects of a congestion charge in Rotterdam are. Next to this I will present the slot reservation system. I will show what the advantages and disadvantages are of this system.

After this review I will elaborate on which system is most feasible. Finally, in the conclusion, I will point out what kind of governmental action I think is necessary.

2. Theory

The first researcher to address the congestion problem theoretically was Nobel Prize winner William Vickrey. He is seen as the 'father' of congestion pricing concepts. He first researched the subway cost in New York, and how they should be structured in order to utilize the system efficiently (Vickrey, 1955). This paper was the starting point of a lot of literature about congestion pricing.

In the beginning there was a focus on the optimal and efficient use of the systems. Soon researchers found that in theory this sounded nice, but most ideas turned out to be non-feasible in real life. Therefore they looked for so called 'second-best' congestion pricing (Nijkamp, Rietveld, & Verhoef, 1955). This concept means the following: since it is impossible to price all actions by agents [first-best], we have to look for a reduction in output by an increase of cost for agents. In practice this means: output [road usage by agents] comes with some negative externalities [less road available for other agents]. These negative externalities are not included in an agent's cost-benefit analysis. To include these in its consideration, governments can for example introduce a toll.

In order to control congestion, it is very important that there is a good understanding of how this congestion is caused. Obviously, traffic jams arise when the demand [for road] exceeds the supply. Then there are too many cars that want to make use of a certain road.

A simple solution, one that seems to enjoy great popularity by policymakers, is to expand the supply. Building new roads and expanding existing ones not only solves the problem but it also creates new jobs and stimulates the economy. It is questioned however, if this solution is really effective in solving the problem. Even if the enlargement of these [new] roads is sufficient to meet the [old] demand, there is another problem. People will anticipate this change in supply and more people are going to make use of the road. There will be a new, higher, demand which possibly exceeds the new supply.

Besides this paradox, described by Braes (1968), solutions like this are often very costly. Not only does [local] government have to make huge investments, there is more often a lack of space in our crowded country. This makes public space very valuable and the expansion of roads thus costly.

Policymakers and researchers soon started looking for other solutions. Solutions that are less costly for government. Where the above mentioned measurement looks at enlarging supply, other solutions focus on rearranging the supply or decreasing the demand.

Yang was the first author to research the feasibility and theoretical application of so-called High Occupancy Vehicles (HOV) lanes. In an article that Yang wrote with Huang (1999), they show that in order to get the first-best pricing for a social optimum, there has to be variance between the toll for different lanes and different points of time. These differences in supply would better match the demand of different users. Therefore the congestion would, for a large part, disappear. In later papers, Yang shows that it is very difficult to determine the optimal pricing schemes, because of unknown demand functions.

The creation of HOV and Carpool lanes was very popular at the end of last century. Policymakers saw it as the solution to their congestion problems. The idea behind it was very simple. The amount of cars on the road was excessive, but it is hard to get people to avoid the highway. By making it profitable for people to carpool, demand would fall while everybody still could make use of the road. In theory this is not only solves congestion problems but decreases the per person output of harmful exhaust gasses. Unfortunately, in practice the idea turned out to be non-feasible.

In the Netherlands a carpool lane was opened on highway A1. The 28 million euro costing lane was only available for cars with 3 or more passengers. There was only a small rise in the amount of HOV's. For most people it turned out to be too inconvenient to park and meet people at the specially created carpool parking's. Meanwhile, this HOV lane was not accessible by solo drivers, which was unfair and in contradiction to the law according to former minister Tjerk Westerdorp. The judge ruled in his favour. Policymakers dropped this policy as quick as possible and the carpool lane was closed[1].

Expanding and rearranging supply turned out to be ineffective, so policymakers turned their attention to the demand. Lowering demand is another way of tackling the problem. As mentioned above; the enlargement of supply is often costly or hard to realize. Downgrading the demand can be profitable, but there will be other problems. In order to decrease the number of cars on the road, we have to make car usage less popular.

This can be done by raising the cost for car usage. An example of this is extra tax on car ownership or on roads.

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[1] http://www.nueens.nl/698/de-eerste-en-laatste-carpoolstrook-van-nederland.html

Another way to make the car less attractive is by enlarging the attractiveness of its alternatives. For example, lower the prices in public transport or reward people for not making use of a certain road.

This last example seems a little bit weird, but this is actually done. It is one of the latest measurements that the Dutch government introduced. People that had to make use of the A15, or did make use on a daily basis, could sign up to a register. If they could show that they did not make use of the route on a certain day, they could earn a financial reward. Other measurements that were recently used to lower demand are: dynamic maximum speed, increase parking fees and tax deduction for home workers. [2.]

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[2] Ministerie van Infrastructuur en Milieu (2011). *Resultaten Mobiliteitsprojecten.* Den Haag: Ministerie van Infrastructuur en Milieu

3. Congestion Charge System

Over the years, a lot of different pricing systems have passed the revue. Only a couple of these have been proven successful. One of the most famous pricing systems is the system in the capital of England, the London Congestion Charge [LCC]. This system is considered to be one of the first good working congestion pricing systems in Europe. There were other systems that have proven successfully, but the LCC was a real pioneer in the western world.

In this chapter I will discuss its characteristics. After this I look at the congestion policy in the Netherlands. I will model the situation in London and try to find the elasticity of demand. This makes it comparable to the situation in Rotterdam. I will conclude this chapter with an analysis about the possibility of the introduction of a congestion charge in this area.

3.1. The London congestion charge

In 2003 a congestion charge was introduced for some categories of motor vehicles within the so-called Congestion Charge Zone [CCZ] in downtown London city. This introduction was the outcome of some heavy years of debating, discussing and negotiating between different parties. Already in the late nineties of the last century a couple of reports appeared that revealed a gloomy future for traffic in London. Average speed in the centre was drastically reduced, overall travel times were large and traffic was stuck on every corner. The city was locked, every morning and every evening (Office, 1995).

There was common understanding that something had to be done, so a committee was formed to research the possibilities. The Government office of London published a report: Road Charging Options for London (2000). Soon they found that the solution to solve the congestion problem was not an easy one. In order to make a real change, some kind of charging system seemed to be the only real effective one. The advice of this committee was to introduce a toll for road use in the inner part of the city (Santos, 2008). The resistance against such a plan was, not surprisingly, very high. Not only consumers were reluctant to take part in the scheme, also [small] business-owners complained that their profit would decline because of higher cost of transport and less consumer activity in the stores that lay within the area.

The fact that this project was ultimately realized was mostly due to Ken Livingston, who was at the time running for office of mayor. He was a big proponent of a system like the LCC. The introduction of a pricing system was one of the cornerstones of his electoral statements. The election of him as mayor enhanced him to go through with it (Litman, 2005, p. 19). After a lot of discussion and revising, the London Congestion Charge was finally implemented on February 17th, 2003.

The LCC is a charge that users have to pay upon entering the congestion charging zone, CZ. In the figure in the appendix [A] you can see a map of this zone.
Initially, with the introduction of the system, all vehicles that are in the area between 7:00 am and 6:30 pm, Monday through Friday, were charged 5 pound. The area was a bit smaller at the time. The charge could be paid in advance, on the day itself or the next day.
There are a number of exemptions, for example for residents, two-wheelers, taxis, and emergency vehicles. Residents that live inside the area can pay per week, month or even year. They pay 2,5 pound a week. The system has had some upgrades. Residents nowadays pay 4 pound per week and the original charge went up from 5 to 8 pound. Also some of the terms changed.[3]
The LCC was designed and is managed by Transport for London. This organization is responsible for the entire transport system of the city. The mayor appoints the board members. TfL is also the company that takes care of all the payments. People can pay online, at retail outlets, by post, by phone or by text messaging. The fine for not paying in time, before midnight the following day, is 100 pound. This penalty charge is increased or decreased if paid in time respectively paid too late.
Throughout the whole area there are traffic cameras that register all vehicles. Through automatic plate recognition, connected with a database, it is checked whether there is paid or not.

The system brings forth some problems concerning regulation. Also, like any other pricing system, there are some fraud and privacy issues. Because the vehicles are registered through the scanning of their license plate, there is a risk that there will be fraud upon by replacing license plates with stolen ones. Media reported that on the black market gadgets can be bought that could fool the cameras. In the beginning there was a lot to do about the registration of license plates. In theory, this information could be misused. Government has won the trust of it users. Users saw that the system works pretty flawless and so they were keen to adopt it (Litman, 2005, p. 20).

[3] Booklet by the TfL – What do you need to know about Congestion Charging

3.1.1 Success

The fact that the congestion charge in London is a success is due to multiple facts. First of all; there was public awareness that action was required immediately, or consequences would become worse for everybody. The election of a proponent of a pricing scheme, made it easier for policymakers to implement the system. It seems that having the public opinion on your side is a huge advantage. Later on I will see if that is a property that we have in the Netherlands, more specifically Rotterdam.

Second, the benefits of this system are large enough to cover all its costs. Although it is kind of hard to exactly state what the costs and what the benefits are. Of course there is the cost of hardware and installation of this. Add the cost of maintenance and regulation and you have a good estimate of total costs. However, there will always be hidden costs that are hard to predict.

Take for example the losses of companies and government due to changed behaviour. Maybe less people will enter the congestion zone, or they will buy less.

The benefits are even harder to express in money. The main benefit of the system is of course the reduction of congestion. This saves time and thus money for several stakeholders.

I don't have data on total costs and revenues as described above. There is however data on operational cost and revenues. So how expensive was the London Congestion Charge system? It is hard to say exactly. TfL states that the original LCC project costs were approximately 200 million pounds. This was at the time paid for by the government. The operating costs are paid by the revenues of the system. The last couple of years, these revenues have been significantly bigger than the costs. These net revenues are used to invest in public transport (TfL, 2010). Operating costs are somewhere around 90 million a year and total revenues around 200 million. These revenues are mostly charge revenues. About a quarter of the total revenue comes from enforcement revenues, such as fines for defaulters. For all data, see table 1.

table 1.

In pounds (million)

Cost/Reveneu	**2002-2003**	**2003-2004**	**2004-2005**	**2005-2006**	**2006-2007**
Total Operating Cost	**18**	**98**	**92**	**88**	**88**
Total Reveneus	**20**	**179**	**197**	**210**	**208**
(Charge revenues)	*19*	*122*	*120*	*144*	*154*
(Enforcement reveneus)	*1*	*58*	*77*	*66*	*54*
Net Reveneu	**2**	**82**	**105**	**122**	**120**

Cost of the LCC. *(Source: TfL report 2007)*

3.1.2. Dutch proposals

In the Netherlands there have been many examples in the past with all kinds of schemes. [See (Savelberg & Korteweg, 2011) for example]

The best-known is probably a project called 'Rekening Rijden'. This project has been declined multiple times by several governments. The idea was to install some kind of tracking devices in all Dutch cars. Users would have to pay an amount, dependable on the amount of kilometres driven. The main problem with the project was the fact that individual motorists, united in the ANWB [the Dutch motorists union] were against it[4]. One of their biggest concerns was that transport by car would become too expensive and thus no longer affordable by the minima. Also the alternatives such as public transport are considered insufficient. The public transport in the city of London is of a very high standard. In our country the share of people using public transport is much lower, while the network capacity almost reached its maximum (Kozluk, 2010). A congestion charge will affect relatively much more residents compared to London. However, the most important reason for several organizations to block the pricing scheme in the Netherlands was the fact that no one did believe that it would solve the problem. There was no guarantee that cars would still line up in traffic jams at rush hour. The expectation was that driving would become more expensive, but congestion would still be a huge problem.[5] If this is in fact true is doubtful. London has shown some favourable numbers regarding the reduction of congestion. Also in London there were a lot of sceptics that predicted the same for their city. It seems that this project is now definite has been put off. In the 2010 coalition report, government states there will be no such thing as kilometer charge.[6]

So why should a congestion area in Rotterdam work, where other projects already failed? That is the question I will try to answer in this chapter. I will make a model, and show what the effects will be and whether these effects are big enough to grasp the problem.

3.2. Model

In order to analyse the possible effect of a pricing system in Rotterdam, we have to take a closer look at the situation in London. More specifically, I am interested to see what the elasticity of demand is. This elasticity shows what the effect on demand is of a price raise. With this number, and the total demand for the Rotterdam area, I can show what the effect will be of a congestion charge in our country.

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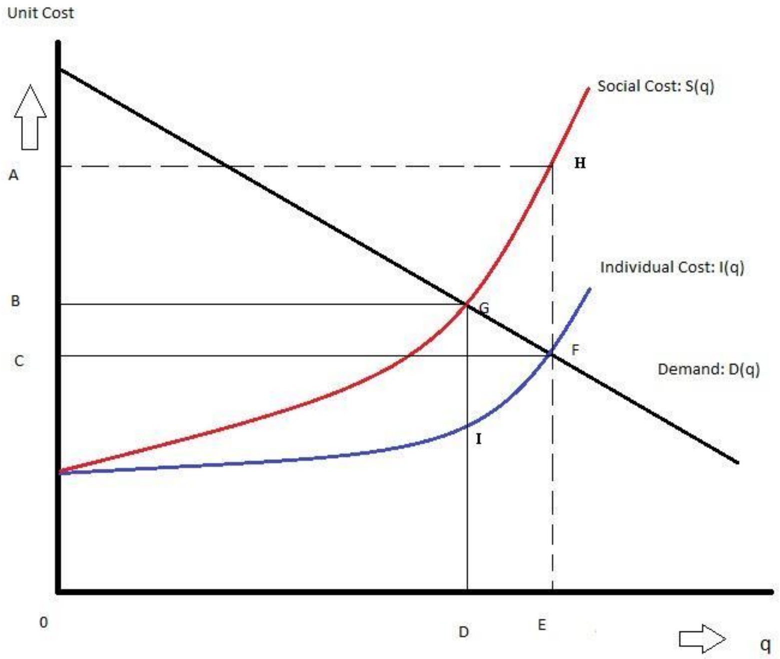
[4] http://retro.nrc.nl/W2/Lab/Rekeningrijden/tegenstand.html

[5] Kampioen: ANWB zegt: stop rekeningrijden. Jaargang 114 nummer 2; februari 1999

[6] Regeerakkoord VVD-CDA; Vrijheid en verantwoordelijkheid, 30 september 2010; Page 28

figure 1:



In figure 1 we can see how the congestion problem arises. On the x-as the total quantity of road use is given, the y-as shows the unit [per km] costs of road. These costs merely exist of time costs. Time is valuable; the more time is spend in traffic, the costlier it is to drive. Optimum is reached where the social benefits [in the form of demand] meet social costs . This is the quantity at point *D*.

The problem is that the individual cost curve lies beneath the social cost curve, off equilibrium. This is because individual drivers only base their decision on whether to consume or not on their own cost benefit analyses. They do not take into account the fact that their presence in the traffic means less room for other. To have a better understanding of the problem I will start by giving the characteristics of lines.

The Demand function: *D(q)* is an downward slope. If costs are high, fewer individuals would want to make use of the road. This is very straightforward.

The individual cost curve looks like this:

$I(q) = a + tv$ (1)

a is some fixed part. It is the cost that one has, even when there is no-one else on the road [*q*=0]. If this is the case, the individual still has to spend some time on the road to drive one kilometre.

Also there are some operating costs for his vehicle. t is the time spend in traffic and v is the value of time.

The time spend in traffic is dependable on speed:

$t = 1/s(q)$ (2)

If the speed [$s(q)$] goes up, [t] goes down. The speed itself depends on the usage of road by others. The more users on the road, the lower speed is. Time spend in traffic [t] goes up.

So time [t] is a function of speed, s [km/h], which itself is a function of road usage:

$s = a - b*q$ (3)

a is the speed when roads are empty [q=0]. If q goes up, speed goes down.
We now have all the building blocks of the individual cost curve.

The social cost curve shows what the use of road by one individual costs to society. This is always higher than the individual cost curve because it is equal to the individual cost curve, plus the cost of the extra time that others have to spent in traffic because less road is available for them.

The social cost curve looks like this:

$S(q) = I(q) + I'(q)*q$ (4)

We can explain equation (4) as follows. First there is the individual costs $I(q)$. These costs are cost for the individual and thus also for the society, which the individual is part of. The difference between the individual and the social cost curve is the fact that, when the individual is making use of the road, this affects society. Because the individual is on the road, q goes up. This makes speed go down and time spend in traffic goes up. To account for this, we add the derivative [$I'(q)$] to the function. By how much speed is going down depends on the number of people [q] that make use of the road. Therefore $I(q)$ is multiplied by q. In summary; the last part of function (4) [$I(q)*q$] is the costs of the additional time spend by all other vehicles because one extra vehicle is on the road.

Figure 1. shows the problem of congestion in theory. We want to be at equilibrium point D. This can for example be done by introducing a tax, as has happened in London. This tax has to be the

size of *IG*. The costs for an individual are then equal to *I* plus the tax *IG*. The individual will only use *D* amount of road, which is equal to the socially optimal quantity.

3.2.1. Demand elasticity

For my further research I am interested to see what know the location and shape of demand is. If I know this for London, I can use this for Rotterdam [with a few assumptions]. At the very least one wants to have a fairly precise estimate of the demand elasticity. To find this elasticity for the London case, we would simply have to find out what the percentage change in price was and the associated percentage change in road usage.

The definition of road usage I will use here is the number of vehicles kilometers per day in the charged zone.[7] The total number of vehicles km per day before the introduction of the charge was 1390 thousand. Afterwards this was reduced to only 1160 (Prud'omme & Bocajero, 2004, p. 3). Demand has thus fallen with [{(1160-1390)/1390} * 100% =] 17%

An interesting fact is that the number of people entering London by vehicle was already declining since 1999. This is mainly due to the fact that bus fares were increasingly cheaper since 1999 (TfL, London Travel Report, 2007). I expect that the number of vehicles kilometre per day would even be higher if it was not for this drop in fare prices.

Knowing all this, we have to make an estimate of what demand would be in 2003 if there was no congestion charge. This is important because the fall in demand [17%] could be caused by other things than the congestion charge. Since fares for public transport were no longer declining and keeping in mind that daily average number of trips by all modes was rising, I think it is safe to state that the 2003 level of number of vehicles km in the congestion zone would have been at least as large as the 2002 level if it was not for the introduction of the charge. We can thus conclude that demand declined by 17%, because of the introduction of the charge.

Calculating the change in price is somewhat more difficult. As we saw before there are always some cost that accompanies the possession and usage of a car, the fixed costs *a*.. To calculate the costs one has to know what these costs are and what the speed of the vehicle is. Prud'homme & Bocajero (2004, p. 4) show that with a q of 1390 [thousand vehicles km per day], costs are 1.61 euro per vehicle kilometer. After the introduction of the charge, individual costs rose because of

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[7] This number means the following: if someone takes a 10 kilometer drive to work and returns home in the afternoon, his total vehicles kilometers per day are 20

the charge. Costs were now estimated to be 1.93. This amounts to a price raise of [{(1.93-1.61)/1.61} * 100% =] 20%

With this numbers, it is easy to calculate the elasticity of the demand. The rise in cost is 20 percent; the fall in demand is 16.5 percent. The demand elasticity is calculated as follows: we divide the percentage of demand change by the percentage of cost change. Thus: -17/20 = -.085. This accounts to a demand elasticity of -0.85. Since demand elasticity is always negative[8], from now on I will only talk about the absolute number of demand elasticity. If the costs rise with 10%, the demand will fall with 8.5%.

To see whether this number is a good estimate, I had a look at other authors. If we look at the literature, this number seems a bit high. This can be explained by the fact that within the London area, there were some really good alternatives. People were happy to switch to public transport in order to save some money.
Other researchers often look at other factors to explain the demand elasticity of road usage. It is shown that income and economic factors have a large impact on car usage (Hanly, Dargay, & Goodwin, 2002).

To determine the price of car usage is very hard. Often the oil price is used to explain this (Goodwin, Dargay, & Hanly, 2004). The cost of fuel is often seen as one of the main variable cost of running a private vehicle. I am interested to see if fuel prices in the Rotterdam area have any effect on total demand for this area. If I know this, it might say something about demand elasticity. To see if the price of fuel has any influence, and how large this effect is, I gathered data about road usage in Rotterdam and the nation price level of the most commonly used fuel: unleaded gasoline 95.

I looked for monthly numbers on the amount of cars passing on the highway in Rotterdam. I collected data on 5 different points on the ring of Rotterdam. Unfortunately not all data was complete. For some months I found data on all these points, for other I only found data on 2 or 3 points. Because I am interested to see the demand for the whole area, I combined this numbers. In the appendix [B] you see the result. The unit of analysis here is not total the vehicle kilometres, but the number of cars per day.

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[8] If price rises, demand will fall. This accounts for almost all goods. However, there could be exceptions, but I will not take them in account here

After this, I found the monthly price of unleaded gasoline 95. This numbers can also be found in the appendix [C].

I ran the following least-square regression:

$$D = a + \beta * P + \varepsilon \qquad (5)$$

a is constant. β shows how much influence the price [P] of oil has on the demand. This is the slope of demand.

The outcome [see also the appendix [D]] was:

Demand = 205227.9 – 27537.15*price (6)

So if price goes up with 10 cent, demand falls with +/- 2750 cars.
Lets see what this means. If government introduces a tax of 17 cent on gasoline, this means that with the most up to date price of fuel of 1.70 euro [October 2011] people now pay 1.87. The elasticity of demand is as follows. Old demand is: 158414. New demand would be 153732. That is a rise in price of 10% and a fall in demand of 3%. This means price elasticity of demand is - 0.3.
One pitfall of this calculation is that it does not say anything about the amount of kilometres driven.

The calculation of the price elasticity of demand has been done by other authors as well. One recent example is the paper by van Reeven (2011). In this paper he finds that there are several variables that influence the road usage. The research is based on data of fifteen European countries, including the Netherlands and the UK. In order to analyse the effect of wealth and ageing on total car usage, they estimate a model with the following variables: average income per capita, the price of car usage, the working population and the elderly population. These are the explanatory variables; the dependent variable is the total inland transport performance by private cars, measured in passenger-kilometres. This analysis is thus based on passenger kilometres. This number not only takes in account the kilometres driven by a car, but also the number of people that are in the car. If it is the case that more people carpool, this calculation controls for that.

The price of car usage here also is approximated by fuel prices, more specifically: unleaded gasoline 95.
When he runs the model, he gets the following findings. The significant short-run elasticity's for fuel price is -0.07. The long-run elasticity for fuel price is -0.15.
This is interesting and it kind of contradicts with our earlier findings. As the researcher shows, the price of car usage has little influence on total passenger-kilometers.

We now have three levels of price elasticity for car usage. My findings when comparing oil prices and demand for Rotterdam is 0.3. The price elasticity of demand that Reeven (2011, p. 375) found is only 0.07. There is a much quoted paper by Hanly et al (Hanly, Dargay, & Goodwin, 2002). This paper, that uses the same kind of equations as van Reeven, gives a mean fuel price of 0.10 in the short run. For the long run this number is 0.29.

The elasticities as cited above are almost all roughly on the same level. The unit of analysis however, is different. My own findings are based on the number of cars passing, where van Reeven calculates total passenger kilometres.
The one I found for London, of 0.83, is clearly far above the level of the rest. There can be several explanations for this.
First of all there is a big difference in the data used to compute this number. The data I used compares the year before the introduction with the year after the introduction. This is only a small amount of time. The other researchers looked at time spans of several years.
A big difference between the researches is also the definition of car usage. The number I found in London, took in account all individual cost of driving. This includes not only the fuel cost, but also the time spend in traffic. Other researches only took in account the direct cost of driving a car, namely the fuel costs.
Another difference in the computation is the number of vehicles that are taken into account. Most researchers looked at the situation in a whole country, or even continent. These researches are more a reflection of the road usage throughout several years, compared with the fuel prices at that time. This is also what I did with the Rotterdam area, which not surprisingly was almost the same. The elasticity I found for London is more a snapshot.

The fact that price has little influence means that pricing policies, such as extra taxes or toll, would have little effect. Whether this means that some kind of pricing system in parts of the Netherlands, such as Rotterdam, would have no effect is hard to say. It could be the case that for that area the usage goes down. The total nationwide effect of this could be so small that there is no big change in total car usage of the Netherlands. This does not automatically mean that the project should be considered as a failure.

3.3. Rotterdam

That I choose Rotterdam as my research object is partly due to the high congestion in this area. I question whether a congestion charge in this area could reduce this congestion enough. To know what enough is, we have to have some kind of basic level congestion that is allowed.
In the mobility report of 2008, the KiM[9] takes a look at the ratio between the intensity of a road and its capacity. They call this the 'Intensity' to 'Capacity' ratio, or short: I/C. With the intensity is meant: the number of vehicles that pass a certain point in one hour. Capacity is the critical density that the government used. They set this number to 2150 vehicles passing per lane per hour (Jorritsma, 2008).
The KiM states that whenever this I/C ratio is lower than 0.7, traffic flow is at a good level and no jams will occur. This is thus the number that we are hoping to find for the Rotterdam area. With an I/C ratio of 07.-0.8, traffic flow is moderate and there is a good chance on traffic jams. Any I/C ratio above 0.8 means that the flow of traffic will be bad and jams will arise.

I have collected data on the number of vehicles per hour on average in 2010. You can find the results in the appendix [E].
I first looked at what time it was most crowded. You can find this in the table under time.
I know what the demand was, because this was simply the number of vehicles passing in 2010.
To calculate the maximum demand, the capacity, I simply multiplied the number of lanes with the maximum capacity per lane. Outcomes can be found under *Max Veh/H*.
I now have all the tools to calculate the *I/C ratio*. What we see here, is rather remarkable.

Out of 14 points, 9 scored - [bad]. Traffic jams are sure to arise at these points.
I calculated per point what it would take for these minuses to become moderate [I/C = .75].
What stands out from the data is that at some highways, a decline of 20% is needed. Even then, traffic flow is just moderate. It is seemingly impossible to realize. This means that the total cost of driving would have to go up with a lot more. We already saw that a 10% rise in the price of

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[9] KiM stands for Kennisinstituut voor Mobiliteitsbeleid (Institute for Mobility Policy). The organization, which is part of the ministry of traffic, brings out a yearly report on the situation of mobility in the Netherlands.

oil, which can be seen as a good benchmark for car pricing, reduces demand by a maximum of 3% in the long run. In order to make a real difference, there would have to be huge price raises for road use.

3.3.1. Bussines versus individual traffic

In the analysis above, I have not yet mentioned the properties of the traffic on the Rotterdam roads. There is a difference in private transport and business transport. Business transport, which is merely freight, is expected to be much more rigid with respect to price changes (Graham & Glaister, 2004). The reasoning behind this is as follows: Business traffic often has a greater importance attached to it. Goods have to be delivered, in order for business to work efficiently. If there is a price raise for the use of road, this business traffic still will make use of it. It would take a much higher raise in total cost in order to make a demand drop. We can say that the demand elasticity for trucks and other business traffic is much lower than with private transport.

I now have a look at the roads round Rotterdam, to see what the ratio business to private traffic is. In the dataset I use, the Rijkswaterstaat[10] distinguishes 3 types of traffic. L1 is passenger cars, L2 light freight, L3 heavy fright. I will consider L1 as private traffic and L2+L3 as business traffic. I found data on 3 out of 4 highways around Rotterdam. In the appendix [F] you can see the table with data.

There are some things that stand out.

First of all, which is not so clear in the table but stands out from the data, the business traffic is much better distributed throughout the day. In the data on private traffic we see a high peak in the morning (7:00-8:00) and afternoon (16:00-18:00). The business traffic is distributed over the whole day. See the appendix [G] for a graph. This might be explained by the fact that private traffic, consists merely of commuters. These are people that have to start and end working on pre-fixed times. They are more tied to a specific schedule to leave home and go to work at certain times. Business traffic has more options. It does not really matter if the package arrives at 11 o'clock or 1 o'clock.

Another thing that stands out from the table is the fact that the ratio business versus individual traffic is much higher on the southern ring, the highway A15. Although there is no data available on the origin and destination of the traffic, this is likely due to the fact that this road is connected

[10] Rijkswaterstaat is an executive agency of the ministry of infrastructure and Milieu. Until 2010 it was part of the ministry of Traffic and Water management. This agency regains all the data for political purposes. They developed the application from which I collected the data.

to the harbor. The port of Rotterdam is one of the most important and busiest ports of Europe. There is a lot of import and export of goods. These goods travel into various places in Europe. This happens via the water and air, but most of all via our highways (KiM, 2010). The A15 is a real key road in this, since it is the highway that leads from and to the harbor. We see that this road has a share of approximately 20% of business traffic, compared to 8-10% on the other roads.

The last thing that stands out from the data is the fact that the congestion is merely due to the private traffic. If there was no business traffic at all, there would still be jams on most roads. To see why, we have a look at the I/C ratio table in the appendix [E]. The total disappearance of business traffic would not be enough to account for the percentage needed to get the sufficient I/C ratio's. Traffic flow however, would be better than it is now. A exception to this seem to be the highway A15; a reduction of traffic with 20% will make a significant difference here. With the total reduction of business-traffic, not only the number of cars is reduced, but total amount of kilometer road that comes available will be even larger. This is due to the fact that light and heavy fright, vans and trucks, take up more space then cars.

As we have seen in literature (Arnott, de Palma, & Lindsey, 1993); business traffic is much more rigid to price changes. This means that price reductions as well as price raises won't have much effect on this. Introducing a pricing scheme mostly affects the consumers, using private cars. As I mentioned before, the effect on this private traffic is hard to predict. Also it is much harder to introduce a pricing scheme for consumers, because this market is much more fragmented.

Businesses are already subject to several pricing schemes, so it would maybe be easier to introduce a congestion charging system like the LCC here. This could be a good idea for the A15, where the decline of business traffic can have a large effect on total traffic. The problem is that this kind of traffic is not much amenable to a price raise, so total effect could be small.

3.4. Conclusion

Introducing a pricing system in Rotterdam, that looks like the congestion charge in London, will probably not be very effective. That is, if the intended effect is to completely erase or significantly reduce congestion. The introduction of a charge can be seen as a price raise or extra tax on driving. The oil price is a good benchmark for the effect such a raise has on demand. As we have seen, the likely effect of this raise is very small. This we can conclude from my own findings and that of others.

However if the goal is to raise funds the project could be a success. We have seen in London, were the system was undoubtedly a great success, this was mainly due to other factors. With the money raised by the charge, government invested heavily into public transport. A lot of new bus and metro lines were opened. Not only that, but because these investments were paid by the revenues of the LCC, there were almost no price raises on the tickets. This made the public transport a good alternative for commuters. Some say that the LCC was a big success because of these side effects, not because congestion was reduced that much. The data supports this finding.

I don't think the same could hold for Rotterdam. First of all our public transport system is not a good alternative for most drivers. In London more people were already used to taking the subway or train, in our country this is valid for a small minority only. Second; In London there was a lot of traffic into (morning) and out of (afternoon) the centre, in our case the traffic is stuck in all directions. For most traffic, Rotterdam is much more a passage than an endpoint.

Last but not least, the fact that this system was introduced was mostly due to the overall opinion that something had to be done, immediately. Although congestion can be very costly for our region, this believe is less strong in the Netherlands. Recent examples of this are the failures on 'Rekening Rijden' and carpooling. The fear that demand will not drop enough in order for congestion to disappear or degrease seems founded. I have shown that there will only be a small drop in demand. With a congestion charge it is plausible that users will have to pay more, but there will be no real improvements concerning congestion.

Maybe in the future, when the problem will become more and more costly, our country is ready for a congestion charge. It seems that this is not yet the case.

4. Slot reservation

In this chapter I will elaborate on another interesting system that I came across in the literature. It is called a slot reservation system. There are several reasons I found this solution very interesting. I will give some potential benefits and flaws of this system later on.

4.1. The System

The first paper to discuss this solution was a paper from Akahane & Kuwahara (1996). In: A Basic Study on Trip Reservation Systems for Recreational Trips on Motorways, they study the effects of trip reservation systems on holiday based on a state-preference survey. In the Tokyo Metropolitan area very heavy congestion appears four to five times a year, because people simultaneously go on holiday. The conclusion of their research is that there is a maximum adjustment in the departure time that people are willing to make. This maximum adjustment is not large enough to fully eliminate congestion. There will always be some events which can't be controlled, for example accidents or weather. As I stated earlier, it is seemingly impossible to eliminate all congestion, no matter what system is used. I am only interested in the feasibility of such a system.

In our infrastructure today there are all kinds of systems that focus on the flow of traffic. Think for example of the matrix-signs above almost all our highways. These signs make it possible to maintain changing maximum speeds on these roads. This is very useful in the case of accidents or unusual pressure on some parts of the road. Flexible maximum speeds make it easier to control the flow of traffic. It is a way of controlling the flow (Savelberg & Korteweg, 2011, p. 26).

The system I propose in this chapter works via the same principle. The more control there is on traffic, the less congestion there will be. Basically, it is a form of rearranging the supply. With the reservation system, the optimal system departure times are equal to the individual departure times of people (Koolstra, 1999). Easily said: If an individual [a system or its operator] is able to rearrange all individual movements, one can do so [more] efficient [than before].

Here I try to sketch what the reservation system, ideally, looks like. There have been made several designs [(Ravi, Smaldone, & Iftode, 2007); (de Feijter, Evers, & Lodewijks, 2004); (Liu, Son, Lee, & Kapitanova, 2009)]. Unfortunately, the system has never been implemented, so I can only describe it in my own way.

The reservation system has basically two major components; the reservation centre and an organization that takes care of everything. Companies and/or individuals can make a reservation from their office or homes. They reserve a time slot on a certain piece of road. The organization knows how many slots are available, because this is equal to the maximum road occupation. The reservation centre automatically calculates whether a certain slot is available. If so, access is granted. Granting the access means that the 'reservee' is able to enter the highway within a certain time limit. To ensure that 'non-reservees' aren't able to enter these slots, we have to think of some kind of access system. This could be entrance barriers at the ramps of the highways. However the installation and controlling of this hardware might be very expensive. The introduction of (high) fines for unauthorized use could also solve this problem. This system requires some kind of detection system, for example license plate registration. This looks a bit like the system in London.

What the exact design of the system exactly looks like also depends on the goals that the government wants to meet. The government could go for the full introduction, implementing the system in the whole country or at least a great part of it. I might however be a better idea to test the system on a few routes first, maybe even test it in the business sector first. Government has to decide on a lot of things, depending from price and price variation to the kind of enforcement instruments. For this thesis, it is not relevant what the design exactly looks like. The mechanisms will be the same, as are the main goals.

4.2. Pitfalss

A big issue with this system, maybe even more than with other systems, is the fairness issue (Wong, 1997). Of course there is, like with the other systems, the question whether it is socially desirable that users pay extra for the use of road. As shown before, in theory this is the only way to reach a social optimum. Unfortunately, there is a lot of resistance against congestion pricing schemes.

The reservation seems fairer than the London system, given the fact that people pay an amount that depends on the distance driven. Larger slots will cost more for example. But the fact that people will have to pay for something that was free before can cause some problems. We have seen before that the public opinion plays a large part in the introduction of any congestion pricing system.

With the reservation system there is also another problem concerning fairness (Zhao, Triantis, Edara, & Teodorovic, 2010). It is not unthinkable that certain slots will run out. Some slots, for example during rush hour, will be very popular. We should come up with a method to distribute the slots among potential users. This can be on a first come first serve base. The problem with that is the fact that people may be buying a lot of slots in advance and not use them. This also creates room for a black market where early buyers sell slots for much more than market prices. Slots could also be auctioned. This is, as it seems, a more equal approach. The one that values the slots the most will also have the biggest change of acquire them. A problem here is that these bidders with the highest willingness to pay maybe also the more polluting ones. This creates a whole new set of problems. Also it will be very hard to bring sellers and potential buyers come together.

4.3. Potential benefits

Most of the potential problems come from the fact that there has not been an implementation of the slot reservation system yet. This can be big disadvantage if you only consider the cost. Future adaptors can sit and watch and learn a lot from the first users. The costly software systems can be copied, it is know what exact hardware is needed and costly lessons are learned by other for free. But if the Dutch government decides to go through with this system, this can have some major benefits in the future.

To show this I will refer to water management, a sector in which the Netherlands is world leading. (Lintsen, 2002)

It is a strange sight, the thousands of tourists that gather round the famous waterworks of our country; the Oosterschelde storm surge barrier in the province Zeeland. Apart from a huge construction and a lot of water there is not much to see here. Yet, this giant steel construction is one of the most important structures of the Netherlands (Goemans & Visser, 1987). The Deltaworks, which is a collective of the famous Oosterschelde storm surge barrier, the dikes, the dams and other barriers, are unique to this world. The Netherlands lay at some points up to 6 meter below sea level, and without these constructions half the country would have been flooded (Vrijling, 2001). The constructions that we have built attract a lot of attention. The American

Society of Civil Engineers even named the works in Zeeland as one of the seven modern wonders of the world.[11]

From all over the world there is a question for our knowhow on water management. Innovating and investing highly in this sector have led to the leading position that Dutch scientist have on this subject. This is not only good for our international reputation, but it gives some huge advantages to Dutch companies. When Katrina raged over New-Orleans, leaving several dikes destroyed and large part of the state flooded, the help of Dutch engineers was highly requested.[12] Also some of the largest dredging companies are Dutch. They operated in several projects that diverse from the salvage of a Russian submarine[13] to the construction of complete islands for the coast of Dubai.[14]

To stress the important of water management for this country; the crown prince, his royal highness Willem-Alexander, is not only patron of the Global Water Partnership but also chairman of the independent 'advisory board of Water and Sanitation' of the United Nations. All of the above shows that water management once was and still is very important for the existence of this country. Through innovations and investments we are not only able to control it, but we can let the water do the work for us. From a necessity we made our specialty. I think we should be able to do the same with our traffic management. The Dutch road usage per kilometer of asphalt is not only one of the highest in the world; our options to expand our network of roads are limited due to a lack of space. A lot of countries and companies monitor our innovations on traffic management closely, because our situation is a good reflection of some urban areas in their own country (Bovy, 2001). The designing of a good working traffic management system can bring a lot of the positive externalities that we have seen in water management. The reservation system is such an innovative system.

Besides this pioneering function the reservation system has, there are some other major benefits. First of all congestion is likely to be almost completely solved. In comparison to other systems, full is full. This means that one can easily put a maximum number of slots in the market. If this number appears to be too small or large, it can [easily] be adjusted. One of the major concerns with other systems that have been introduced [but never implemented] in the Netherlands was that congestion would still appear. With this system, this is solved.

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[11] Sit van ASCE: http://www.asce.org/content.aspx?id=2147487305

[12] http://www.soros.org/resources/multimedia/katrina/projects/CantDoNation/story_DutchCanTeach.php

[13] http://en.wikipedia.org/wiki/Russian_submarine_Kursk_explosion

[14] http://en.wikipedia.org/wiki/Palm_Islands

Besides cost reduction there is also the revenue of the slot sale. It is hard to give a (estimation of this) number, but the profit of such a scheme could be large. If this profit is invested in other means like public transport, a lot of people benefit from this. I showed before that some researches' showed that it was not the system itself that made the LCC a success, but it was the investment of profit into the expansion of the roads and public transport that made a real change. This could also work here.

4.4. Business versus individual traffic

In the previous chapter I have already mentioned something about the difference between business and individual traffic. I then stated that the introduction of a tax scheme would have not much of an effect on business traffic, since their demand elasticity is rigid. Introducing a taxing scheme solely for business traffic thus seems to be a bad idea. With the reservation system, things are completely different.

It is easier to address only firms, since they are better organized. If a scheme is introduced, it is possible to assert only companies.

Also, firms are commonly used to plan their visit on the roads. They make use of all types of schedules to calculate the best time to deliver the goods. I already showed in the previous chapter that companies are better capable of planning their trips outside rush hour. An introduction of a reservation scheme would be easier for these firms since they are already used to plan the arrival and departs of their trucks.

Introducing a scheme only for businesses would however not completely solve all the problems. I have shown before that business-related traffic is only a small part of total traffic. Things are different for the A15, were freight takes up a large amount of the road. So introducing a reservation system here could be a good test case. If the system seems to be a success, overall introduction could become an option.

4.5. Conclusion

The reservation system is an unknown congestion pricing scheme with some major benefits. There are however some large concerns and there is a lot of uncertainty. Where the uncertainty with the taxing scheme lays in the question whether it is effective enough, the biggest concern

with the reservation system is the feasibility of the system itself. The out roll of such a scheme has never been done before. The uniqueness of the project also has some advantages, with respect to becoming a pioneer.
As with the taxing scheme, the reservation system will be seen as another congestion pricing system. Public opinion has to be on your side in order to make it a success. A lot of people will be reluctant to pay for something that was free of charge before.
Another concern that the public might have, the question whether it will solve anything, can be taken away. I showed that congestion could almost disappear, because one is able to control the total supply of road. Demand will adjust to this.
Off course there are some major concerns about investments that have to be made in hardware. Apart from that I think it is feasible to introduce a scheme like slot reservation system in the Netherlands.

In the next chapter I will make a comparison between the two systems. Here I will take into account the feasibility, total costs and public opinion.

5. LCC versus Slot Reservation System

In this chapter I will compare the two systems that I described in previous chapters. I first had a look at the London Congestion Charge in the Netherlands. It seems that, in theory, such a system could be a good idea for the Netherlands, and more specifically Rotterdam. After this I took a look at the Slot Reservation System. This system, broadly discussed by many authors, has in contrast with the LCC not been implemented yet. This makes it kind of hard to compare the two systems, but I will try to do so in this chapter. I will draw a conclusion about which system is most interesting for the Netherlands.

5.1. Practical problems

As discussed before, each of the systems has its own pitfalls. The main concern with LCC is the public opinion. The public opinion has to be in favour of a taxing scheme, in order for it to work correctly. Of course the same holds for the slot reservation system. However, this last system has a unique selling point, namely the (almost) total reduction of congestion. I have showed before that this was one of the main concerns with previous schemes that have been introduced in our country. With the LCC, there is no certainty about the reduction of traffic jams.

The LCC has though, some other features that make it favourable. The most important one is the feasibility. This system is much easier to introduce in our country. The introduction of a slot reservation system demands some large investments in data centres, reservation centres and access controlling systems. Apart from some kind of enforcement system, the LCC only demands a good detection system, for example license plate registration. Such a system is already in use on a lot of highways in our country (RWS & DVS, 2010) . Of course there is also need for an organization that is in control of payments and enforcement, but a reservation system requires the same. Overall, the technical aspects of this system are less complicated and thus cheaper. The fact that several similar systems have been implemented in various countries is, despite the pioneer function the reservation system can fulfil, a big advantage.

The Slot Reservation System is more demanding towards users. Reservations have to be made, on forehand. With this system it is harder to go on an unplanned trip. This is one of the main benefits of the LCC. If you decide to make use of the road, this is always possible.

5.2. Tax versus quota

There is another way of looking at this problem, by comparing what economic theory says about it. The comparison between a LCC and a Slot Reservation System can be seen as a comparison between the introductions of a tax respectively a quota restriction. I will show how this works. Also I show what the welfare effects of both systems are.

On first sight there is no big difference in a tax and a quantity restriction. Both measurements have the same purpose and seemingly the same outcome. They both steer quantity to a lower, desired, outcome. There are however some differences, that affect welfare and equality. Without any of the two policies the market is in equilibrium, however not in one that is at a social optimum. I have already showed this before, in the chapter on the LCC. The graph below looks a bit like the one of that chapter, but there are some differences.

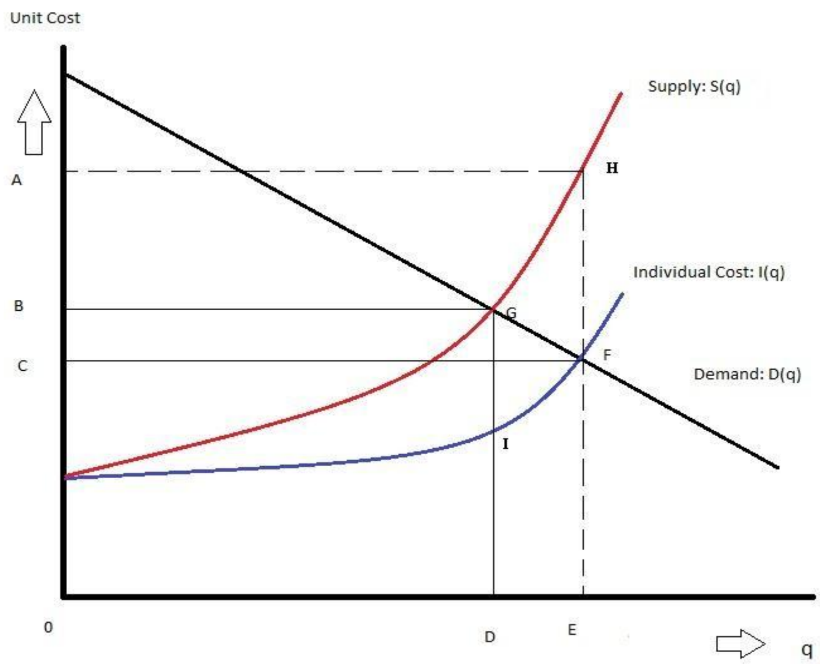

Figure 3

On the X-as we find q, which again is the quantity of road use in vehicle kilometres . On the Y-as we find the unit costs, this means the cost of making use of the road. Demand, D(q), is an straight declining line. The idea behind this is simple; the more costly it is to make use of the road, the less road is demanded. I already explained the Individual Cost curve in the previous chapter.

Supply is the same as the social cost curve. The reasoning behind it is also the same. When an individual makes use of the road, there are certain costs that he makes [individual costs]. The amount of cost he supplies are however even higher. This is because there are certain costs, namely the fact that less road is available for others, which he does not take in account. When for example individual vehicle kilometres per day is at level *E*, the demand is *F*, but supply is *H*. Costs *FH* are costs the individual does not take in account.

Social optimum is reached at point *G*, where supply and demand intersect. We are currently as point *F*, where the individual sets its own cost equal to the demand. This is part of an individual cost-benefit-analysis.

We want to reach point *G* and there are two ways of doing that, by introducing a tax or a quota. We could levy a tax on individuals that is equal to *IG* . If this happens, the Individual Cost curve shifts up and intersects the Demand curve at point *G* . The individual vehicle kilometres per day is now at level *D*. In the old situation individual costs were only *I*, but because of the tax, they are now equal to [*I*+*IG* =] *G* . The individual cost-benefit-analysis now has the same outcome as the social optimum.

By setting a quota that has the size *D*, the same social optimum is also reached. Setting this quota means basically that individuals are not able to make more use of the road then *D* vehicles kilometres per day. Not because they don't want to [their cost-benefit-analysis has not changed], but because there are no more slots available.

The measurements apparently have the same outcome but there are some differences.

The big advantage of a tax is its revenue. If a tax is imposed the demand declines, but there still is some demand. The individual motorist for whom the benefit, at that price, still exceeds the cost will make use of the road. The motorist for whom this is not the case will not.

If we look at the figure we notice a few things. Total demand is decreased, from *E* to *D*.

All the individuals that make use of the road pay a charge the size of GI. The revenue for the government is *GI* times the number of vehicles kilometres per day. The total revenues for every individual are thus *GI**D*. This amount can be substantial. A tax can be seen as shifting the demand, but still receiving the willingness to pay of users, be it at a lower level of users. With a quota imposed, there is no tax revenue. The supply of road per person is given, namely *D*. How the available road is divided between the people is unknown. It can be on a first-come-first-serve base. Another possibility is an auction. Unless a system is developed where there has to be paid for the road, there is no extra income for the government here. There is however a big loss of welfare, because people cannot make use of something where they are willing to pay for. This willingness to pay is unused, which leads to a loss in total welfare (Sharp, 1996).

Seemingly taxing is better than quota. First there are the revenues for the government and secondly there is a lower loss in welfare. However, imposing a quota has one major advantage. This can be seen if we compare this model to the reality. In reality the demand is unknown. We know that at certain times of the day demand will be high. We also know that on some days demand for road is high, but there is a lot of fluctuation in this. Because demand is unknown, the right taxing-rate is also difficult to determine. This is one of the major concerns of the stakeholders regarding the project 'rekening rijden'. The stakeholders were afraid that this system, which can be seen as a tax scheme, wasn't going to solve congestion. The major concern was that although there was a tax, demand would still exceed supply. In that case motorist wouldn't be helped by such a measurement at all. They would pay (more) to make use of the road, but there would still be traffic jams.

With a quota this problem can be solved. By simply calculating what the maximum supply is of a road, a quota equal to this can be set. For a road this would mean that you would have to calculate its maximum capacity. This is relative easy. When dealing with an urban area, or a network of (high)roads, it gets complicated. Because it is hard to predict where on the network the demand clusters, there is the possibility that at some points traffic jams can still arise at certain points.

5.3. Fairness issues

Besides practical implementation issues, there is also a difference in fairness between the two systems. I already stated that the reservation system would be fairer, because the distance driven has a direct influence on price. However, with the introduction of the reservation system [the quota], there are going to be people that do not get access to road even if they have a high willingness to pay. There will be a loss of people with a willingness to pay that would make use of the road under the taxing system. It also depends on the alternatives that are present. For example; is there another way of transport possible? A commuter might be able to take the train to work, were the transport of goods might be more dependent on the road. It would then not be fair if the individual would get its hand a slot and the company would not.

5.4. Conclusion

I have researched the benefits and drawbacks of both systems. I have come to the conclusion that the slot reservation system has some huge advantages over the LCC. This lies in the fact that a reservation system, if properly working, can solve almost all congestion. The taxing scheme does not have this feature. The idea here is that, if congestion is the problem, then we need the solution to be the one that addresses a quantity issue, and the reservation system does exactly this.

The reservation system is a new kind of traffic management tool, which can be an advantage, as I have described before. At the same time this is a huge disadvantage, because no one knows how [and if] the system will work.

Another huge disadvantage of the reservation system is the implementation issue. First of all there are the huge investment costs to make an operatable system. Second, the system asks a lot [more with respect to the LCC] of its users.

When comparing the two systems, the most important question is what the goals of the policymakers are. If they are only interested in a temporary and not a final solution, the LCC seems preferable. The feasibility and revenue of this system are probably higher. However, it could be that policymakers are also interested in making a real change and taking a pioneer position in traffic management. If this is the case, the slot reservation system is worth considering.

Taking all of the above in account, I think the government should focus on the introduction of some kind of taxing scheme. The reservation system seems like a good idea, but there is too much uncertainty about a lot of things. The taxing of congestion is something that has been done before, with variable success.

6. Conclusion

In this research I have looked for different solutions to the congestion problem. The main question of this paper was; is there a congestion pricing scheme that should be introduced in the Rotterdam area. I have compared two kinds of schemes. The first one was a taxing scheme were people would have to pay in order to make use of a certain [piece of] road. A system like this has already [successfully] been introduced in the city of London. I have looked at some of the characteristics of the system there and tried to link this with the Rotterdam area. I have come to the conclusion that although there are some differences, a system like the London Congestion Charge can be a good solution. Note here that this system will not solve congestion. I showed that price has too little influence on road usage. The taxing scheme could however be a good way of raising revenues. If these revenues are invested in the improvement of roads or its alternatives, the introduction of the system can have a positive outcome.

I also had a look at a new kind of pricing scheme, the reservation system. Although the idea is not so young, this system has never been introduced before. I found that in theory this scheme is a real problem solver. However, the fact that it never has been introduced means there is a lot of uncertainty about the outcome of this.

If I was to compare the two, I would recommend [local] government to introduce the taxing system. Overall this system seems more stable and less uncertain. The problem with the taxing scheme is that this kind of scheme has already been introduced in the Netherlands. At the time it was rejected, several times, by multiple parties. If we have a look at the project 'Rekening Rijden' we see that a successful implementation of a congestion pricing scheme in our country is far away.

I think there has to be a mentality switch, before congestion pricing [at both local and nationwide level] will be an option again. In London the election for mayor was a real turning point. Although there was a widespread consensus that something had to be done, this was the real game changer. Maybe if one or several of the Dutch reining government parties openly express themselves in favour of a pricing scheme, we can make a start with it. Until that time it will be hard to convince the Dutch people that congestion pricing benefits us all.

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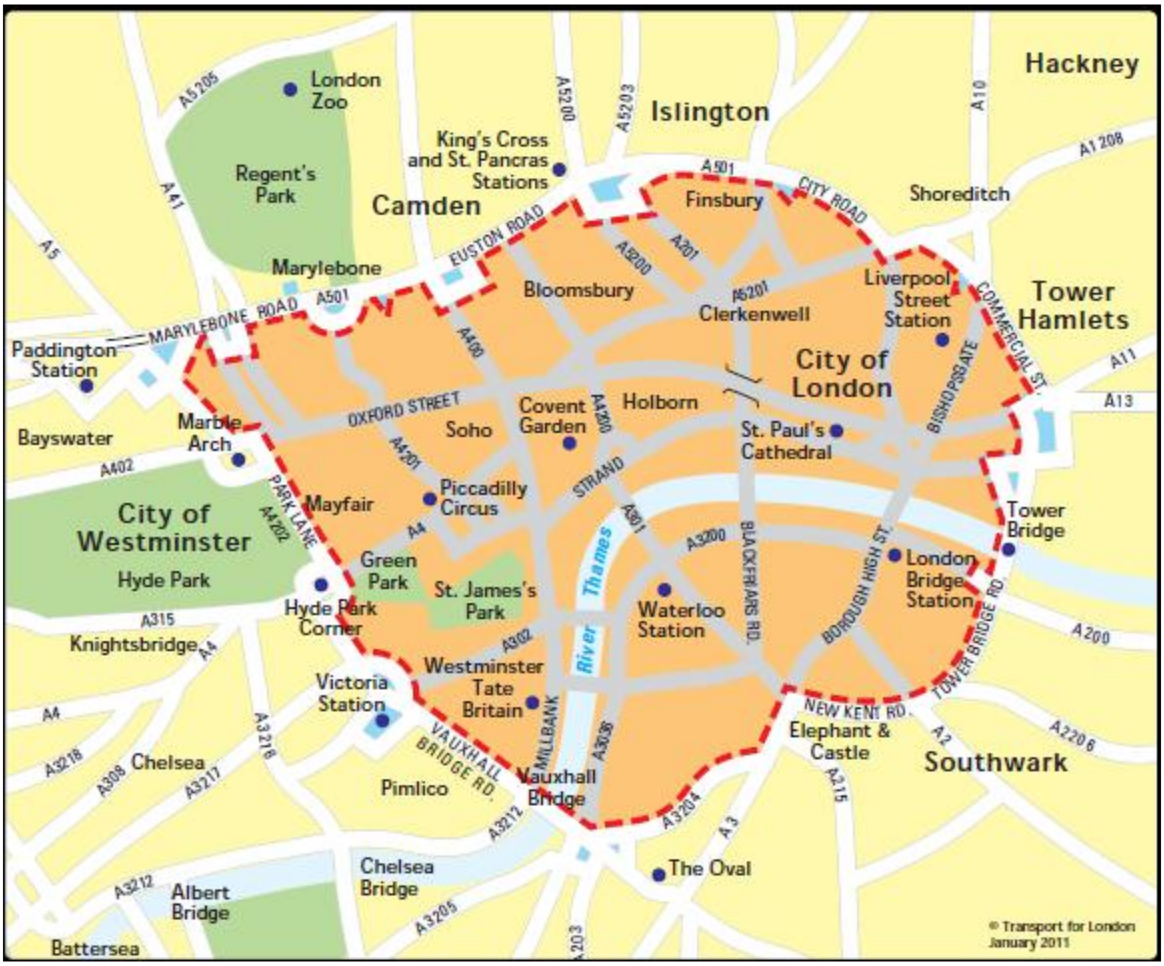
8. Appendix

A - Map of the Congestion Zone in London



B - Number of Vehicles in Rotterdam Area, average on workdays

Vehicles	2001	2002	2003	2004	2005	2006
Januari	184481	187615	153331	158731	159951	157730
Februari	191533	194674	160315	160852	164500	163370
March	196644	200601	164558	167338	164424	165937
April	203071	203991	167124	171712	173082	172815
May	202615	202792	167238	171427	171670	170475
June	202299	200392	168018	170846	172470	179766
Juli	192038	169200	153054	155387	156367	163281
August	181833	147858	156411	157581	161309	172255
September	194608	164026	165057	166889	168959	172804
October	201038	160385	165867	170112	169722	162155
November	198312	163352	166480	167634	166223	162478
December	190184	157004	159201	157492	158248	160296
Total	2338653	2151888	1946653	1975998	1986923	2003360

Vehicles	2007	2008	2009	2010	2011
Januari	151179	155740	154572	150156	155505
Februari	161776	162103	159411	156803	161782
March	163022	164320	163967	164062	162947
April	169410	169388	167837	162645	167803
May	166444	180866	164074	161412	167090
June	147902	181629	166855	165506	171686
Juli	142484	173639	159310	151800	154521
August	135518	162450	153665	154929	156758
September	147752	179053	164261	164518	164419
October	165003	179414	165298	164907	165648
November	170745	177009	163254	162936	0
December	153530	152999	143749	141765	0
Total	1874764	2038608	1926252	1901439	1628157

I found this numbers by using the MTR+ application, developed by Rijkswaterstaat. In this application you can select the roads and see the amount of cars passing on weekdays. I combined numbers of the followings roads: Ring north, A20; Ring East, A16; Ring South, A15; Ring West, A4.

C - Oil Prices in The Netherlands [in Euro]

Oil Prices	Year										
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
January	*1.13*	*1.10*	*1.17*	*1.17*	*1.24*	*1.40*	*1.34*	*1.51*	*1.30*	*1.50*	*1.66*
February	*1.17*	*1.10*	*1.22*	*1.19*	*1.26*	*1.35*	*1.37*	*1.54*	*1.34*	*1.50*	*1.65*
March	*1.14*	*1.15*	*1.18*	*1.22*	*1.28*	*1.46*	*1.43*	*1.53*	*1.31*	*1.56*	*1.69*
April	*1.16*	*1.19*	*1.16*	*1.23*	*1.32*	*1.48*	*1.47*	*1.56*	*1.37*	*1.57*	*1.75*
May	*1.24*	*1.17*	*1.13*	*1.29*	*1.33*	*1.49*	*1.51*	*1.63*	*1.42*	*1.59*	*1.74*
June	*1.21*	*1.14*	*1.15*	*1.25*	*1.35*	*1.48*	*1.51*	*1.69*	*1.50*	*1.57*	*1.71*
July	*1.15*	*1.15*	*1.17*	*1.29*	*1.40*	*1.51*	*1.50*	*1.69*	*1.41*	*1.55*	*1.74*
August	*1.14*	*1.15*	*1.18*	*1.27*	*1.43*	*1.52*	*1.46*	*1.60*	*1.49*	*1.54*	*1.69*
September	*1.15*	*1.18*	*1.18*	*1.26*	*1.45*	*1.36*	*1.47*	*1.63*	*1.45*	*1.56*	*1.70*
October	*1.14*	*1.15*	*1.16*	*1.31*	*1.43*	*1.33*	*1.47*	*1.44*	*1.43*	*1.55*	*1.70*
November	*1.08*	*1.11*	*1.14*	*1.24*	*1.35*	*1.33*	*1.52*	*1.33*	*1.45*	*1.57*	*1.69*
December	*1.05*	*1.12*	*1.13*	*1.20*	*1.37*	*1.34*	*1.51*	*1.25*	*1.43*	*1.62*	*1.68*

- 2001 prices were in guilder. I converted them into Euro [dividing by 2.20371]
- These are mid-monthly prices of unleaded gasoline 98.

Source: http://www.theaa.com/motoring_advice/fuel/

D - Statistics of the Least-Square Regression

Dependent Variable: DEMAND
Method: Least Squares
Date: 04/13/12 Time: 15:52
Sample: 2001M01 2011M10
Included observations: 130
DEMAND = C(1)*OIL + C(2)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-27537.15	6259.155	-4.399500	0.0000
C(2)	205227.9	8656.701	23.70740	0.0000

R-squared	0.131353	Mean dependent var	167482.3
Adjusted R-squared	0.124567	S.D. dependent var	14054.45
S.E. of regression	13149.99	Akaike info criterion	21.82149
Sum squared resid	2.21E+10	Schwarz criterion	21.86561
Log likelihood	-1416.397	Hannan-Quinn criter.	21.83942
F-statistic	19.35560	Durbin-Watson stat	0.460712
Prob(F-statistic)	0.000023		

E – I/C Ratio for the Higways of Rotterdam

The normal route

	Time	Demand	Lanes	Max Veh/H	I/C Ratio	Score	Max	Decline
Ring West:								
Vlaardingen Oost - Kp Benelux	16-17	5428	5	10750	**0,50**	**+**		
Ring East:								
R'dam Centrum - Feijenoord	16-17	10400	6	12900	**0,81**	**-**	**9675**	-6,97%
Ring South:								
Charlois - Kp Vaanplein	16-17	6092	3	6450	**0,94**	**-**	**4838**	-20,59%
Ring North:								
Schiedam Noord - Schiedam	7-8	5713	3	6450	**0,89**	**-**	**4838**	-15,32%
Spaanse Polder - Kp Kl. Polderplein	7-8	4471	3	6450	**0,69**	**+/-**		
R'dam Centrum - R'dam Crooswijk	15-16	6031	3	6450	**0,94**	**-**	**4838**	-19,79%
R'dam Crooswijk - Kp Terbregseplein	15-16	5499	3	6450	**0,85**	**-**	**4838**	-12,03%

The way back

	Time	Demand	Lanes	Max Veh/H	I/C Ratio	Score	Max	Decline
Ring West:								
Vlaardingen Oost - Kp Benelux	7-8	5503	5	10750	**0,51**	**+**		
Ring East:								
R'dam Centrum - Feijenoord	7-8	8949	6	12900	**0,69**	**+**		
Ring South:								
Charlois - Kp Vaanplein	7-8	5857	3	6450	**0,91**	**-**	**4838**	-17,41%
Ring North:								
Schiedam Noord - Schiedam	17-18	5581	3	6450	**0,87**	**-**	**4838**	-13,32%
Spaanse Polder - Kp Kl. Polderplein	7-8	4182	3	6450	**0,65**	**+**		
R'dam Centrum - R'dam Crooswijk	16-17	5801	3	6450	**0,90**	**-**	**4838**	-16,61%
R'dam Crooswijk - Kp Terbregseplein	16-17	5179	3	6450	**0,80**	**-**	**4838**	-6,59%

- Max Veh/ H is the maximum vehicles per hour, the capacity. This is calculated by multiplying the number of lanes by 2150

- The Max stands for maximal intensity of the road, in order to score a 0.75 on the I/C ratio

- Decline gives the percentage drop in demand [intensity] that is needed to get to max

F - Percentage of Business Traffic

2011 (workdays) Forth

	Time	L1	L2	L3	Total	L2+L3	Pct.
Ring East:							
R'dam Centrum - Feijenoord	16-17	*9678*	*484*	*292*	*10454*	*776*	***7.4***
Ring South:							
Kp Vaanplein - Kp Ridderkerk*	16-17	*5957*	*1123*	*648*	*7728*	*1771*	*22.9*
Kp Vaanplein - IJsselmonde	16-17	*5710*	*811*	*602*	*7123*	*1413*	*19.8*
Average					*7426*	*1592*	***21.4***
Ring North:							
Schiedam Noord - Schiedam	7-8	*5330*	*230*	*163*	*5723*	*393*	*6.9*
Spaanse Polder - Kp Kl. Polderplein	7-8	*4158*	*241*	*195*	*4594*	*436*	*9.5*
R'dam Centrum - R'dam Crooswijk	7-8	*5410*	*426*	*289*	*6125*	*715*	*11.7*
R'dam Crooswijk - Kp Terbregseplein	7-8	*3550*	*386*	*288*	*4224*	*674*	*16.0*
Average					*5167*	*555*	***11.0***

2011 (workdays) Back

	Time	L1	L2	L3	Total	L2+L3	Pct.
Ring East:							
R'dam Centrum - Feijenoord	7-8	*8233*	*443*	*309*	*8985*	*752*	***8.4***
Ring South:							
Kp Vaanplein - IJsselmonde*	16-17	*6391*	*422*	*610*	*7423*	*1032*	***13.9***
Ring North:							
Schiedam Noord - Schiedam	17-18	*5361*	*141*	*162*	*5664*	*303*	*5.3*
Spaanse Polder - Kp Kl. Polderplein	7-8	*3967*	*242*	*231*	*4440*	*473*	*10.7*
R'dam Centrum - R'dam Crooswijk	7-8	*5754*	*294*	*189*	*6237*	*483*	*7.7*
R'dam Crooswijk - Kp Terbregseplein	7-8	*3558*	*275*	*189*	*4022*	*464*	*11.5*
Average					*5091*	*431*	***8.8***

**Only data available on workdays in November.*

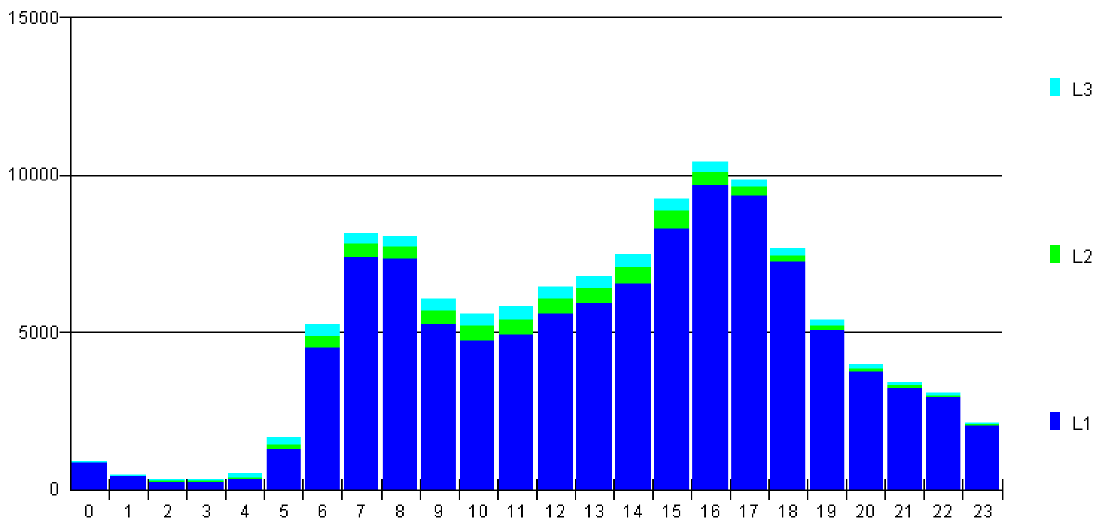
In the last column [Pct.] you can find the percentage of L2+L3 on total traffic. I calculated this by dividing the column [L2+L3] by [Total]

The upper table gives the number for the direction Kp. Vaanplein – Kp Ridderkerk.
The other table gives the number for the opposite direction, e.g. Kp Ridderkerk – Kp. Vaanplein etc.

G - Distribution of Business and Individual Traffic

Intensitity per hour on an average workday in 2010

Highway A16: Rotterdam center – Feijenoord:



Highway A16: Feijenoord – Rotterdam center: