CLEVER
Clean Vehicle Research

Price elasticity
Task 3.2
Part 1

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1. Introduction

Previous research analysed the importance of the factor price and environmental friendliness in the car purchase decision of consumers (see CLEVER task 1.4). The **purchase price**, followed by the **fuel consumption** and the **reliability and security** of the car turned out to be the most important purchase factors. Based on these factors, consumers will select a couple of alternatives. Their final choice will depend on the evaluation of the intrinsic characteristics of the car (e.g. design, performance, comfort) and personal, cultural, social and household characteristics. It has been found that the **environmental friendliness** of the car is not taken into consideration at the purchase of a new car. Consumers do not want to give up other car attributes for the environmental benefit. The willingness to pay for a more environmental friendly car thus depends on the price and vehicle characteristics to be fully competitive with conventional cars. These findings have been tested by means of **two inquiries**. The first inquiry was presented face-to-face on the European Motor show in Brussels (17-25 January 2008). This inquiry was continued online through a web-based survey (March-September 2008). These surveys investigated if the increasing media-attention for environmental problems has an impact on the role of the environmental friendliness in the purchase behaviour of cars. Moreover, it has been researched if policy measures can be an effective instrument in promoting the purchase and use of environmental friendly vehicles. These results are presented in **part A: Survey**. In a second **part B: Literature Review**, a framework will be set up for the evaluation of policy measures. Policy measures will only be effective if they induce the right behavioural changes. In order to evaluate the effectiveness of policy measures, one should not only take the **travelers'attitudes** into account, but also the **price elasticities**. A scheme for the evaluation of policy proposals will be presented where the psychological view (travelers'attitudes) will be linked to the economical view (elasticities) to get an insight in the effectiveness of policy proposals. Based on this scheme, recommendations for the use of policy measures in Belgium can be established.

A. SURVEY

A.1 Scope of the work

The theme of the European Auto & Motor show in Brussels (2008) was **"Sustainable Mobility"** and provided an unique opportunity to investigate if the increasing media-attention for environmental problems has an impact on the role of the environmental friendliness in the purchase behaviour of cars. The survey also investigated if policy measures can be an effective instrument in promoting the purchase and use of environmental friendly vehicles. In short, the focus of the study was to find an answer to the following research questions:

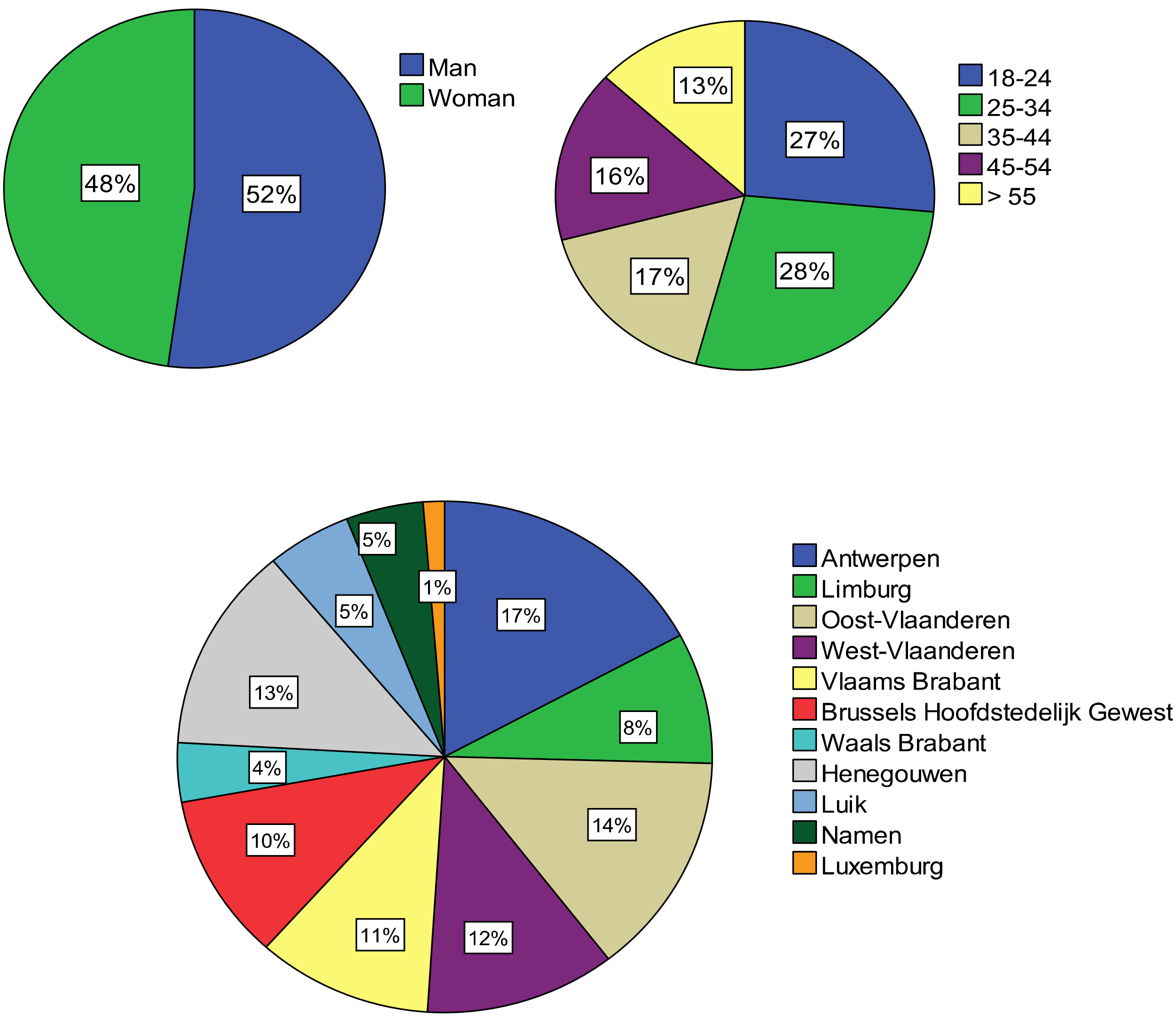
1) Which are the most important purchase factors?
2) Do consumers take the environmental friendliness of the car into account?
3) Are consumers willing to pay more for a cleaner car?
4) Can policy measures have an impact on the purchase and use of cars?

A.2 Sample

The data have been collected by use of **2 inquiries**. The first inquiry was presented **face-to-face** on the European Motor show in Brussels (17-25 January 2008). This inquiry was continued online through a **web-based** survey (March-September 2008). The survey has been screened by the follow-up committee of CLEVER and pretested at the Auto and Motor show. The personal inquiry provided 392 useful answers. The aim of this face-to-face survey was to get more insight in the real purchase behaviour of people within the car purchase process. In an attempt to get a more **representative sample** of the Belgian population, a web-based survey was send around giving another 894 useful answers. Both surveys together provided a total sample size of 1286[1] respondents. It is important to dispose over a representative sample of the Belgian population. In theory, representativeness can be guaranteed if each inhabitant of Belgium has an known and positive chance to be selected. In practice, the representativeness of a sample can be obtained by correcting the deviations of the sample for a number of variables of which the distribution in the population is known. This reweighting of the sample is done by the **post stratification method** (Bethlehem, 2008). Here, it is advised to have an optimal balance between the number of variables and the weighting factors. The larger the number of variables (higher validity with the population), the lower the reliability of the sample (higher weighting factors). In this sample, it was decided to weight the variables **gender** and **living area** of the respondents. The distributions of gender, age and residence are shown in Figure 1.

[1] Both samples could be analysed together since there are only small differences between the face-to-face survey and the online survey without any empirical value ($h_p^2 < 5\%$).

Figure 1: Age, gender and residence distribution of the respondents



Source: Own set-up

Additional information has been collected about the **Belgian car park**. 4,2% of the respondents does not possess a car. 32,8% owns one car, almost 50% owns two cars and 14% owns more than two cars. 34,7% of the respondents is planning to purchase a car in the near future (< 6 months). Of these people, 64,2% will purchase a car as a substitute for another car. 67,4% of the people intending to purchase a car, will buy a brand new car. Almost 1/3 (32,6%) prefers a second-hand car. In 22,4% of the cases, the new car will be an extra car, which will positively influence the number of cars in the Belgian car park. 90% of the respondents prefers conventional fuels: almost 2/3 respondents desire diesel, 1/5 choose petrol and 5,7% prefer LPG. More than 1/3 does not know which alternative fuels or driving systems are available.

A.3 Purchase factors

It was investigated which are the **most important car attributes** at the purchase of a new car. First of all, respondents were asked to sum up spontaneously their 3 most important purchase factors (Table 1). Consequently, respondents had to attribute scores from 0 (not important at all) to 10 (very important) to a given list of car attributes (Table 2).

Table 1: Top 10 spontaneously cited purchase factors

Factor	Frequency	Valid percentage
Purchase price	358	31.8%
Fuel consumption	128	11.3%
Comfort	98	8.7%
Design/looks	81	7.2%
Security	80	7.1%
Brand	43	3.8%
Space	42	3.8%
Size	32	3.1%
Reliability	23	2.1%
Environmental friendliness	22	1.9%

Source: Own set-up

Table 1 shows which purchase factors were spontaneously cited by the respondents. It appears that the **purchase price**, **fuel consumption**, **comfort**, **design/looks and security** are the most important purchase factors with a total valid percentage of 66,1% of the answers. With the aim of deriving the relative importance of individual purchase factors, respondents had to attribute scores from 0 (not important at all) to 10 (very important). The 10 most important purchase factors are displayed in Table 2.

Table 2: Top 10 of purchase factors

Factor	Mean (out of 10)	Standard deviation
Reliability	8.90	0.92
Security	8.68	1.02
Fuel consumption	8.52	1.12
Purchase price	8.45	1.21
Comfort	7.73	1.09
Space	7.60	1.22
Maintenance costs	7.57	1.33
Type of car	7.38	1.48
Warranty	7.13	1.44
Size	7.08	1.40

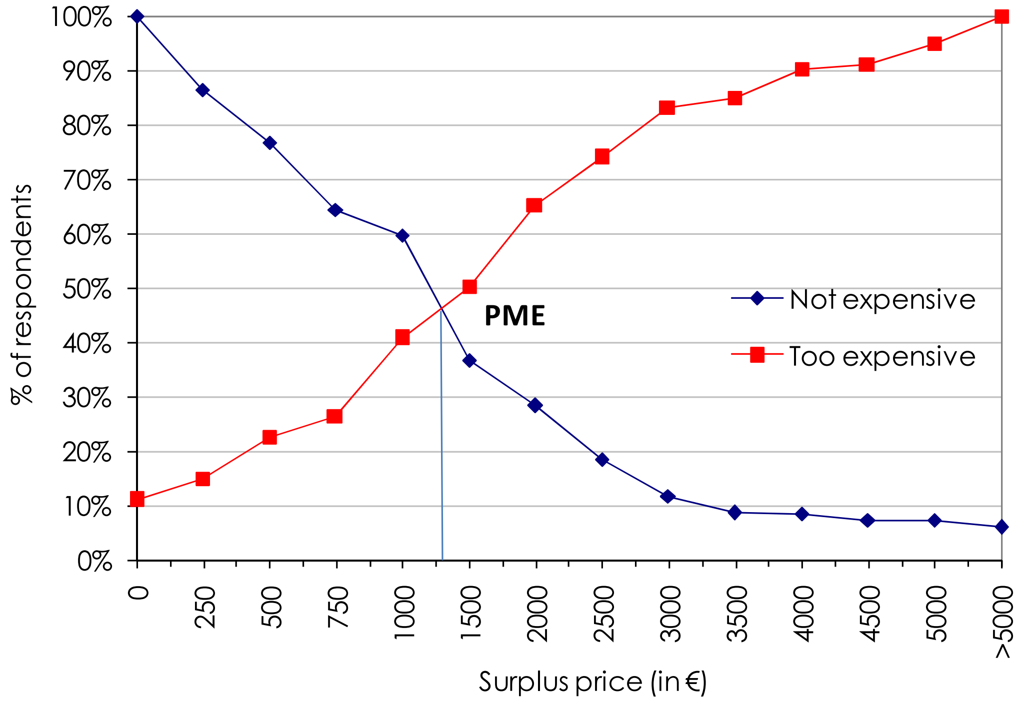
Source: Own set-up

Reliability appears to be the most important purchase factor, followed by **security, fuel consumption, purchase price and comfort**. Space, maintenance costs, type of car, warranty and size finish the top 10. When comparing Table 1 to Table 2, one can notice that 7 factors appear twice in the top 10, namely **reliability, security, fuel consumption, purchase price, comfort, space and size**. These factors can thus be considered as very important. These results confirm previous findings (Turcksin et al., 2007) stating that the first selection of a new car is based upon the evaluation of rational factors (purchase price, fuel consumption and reliability), and where the final choice is based upon the intrinsic characteristics of the car (comfort, space, size, design) and socio-economic characteristics such as personal, cultural, social and household characteristics. The factor **environmental friendliness**, ranked in Table 1 at the 10th position, appears in Table 2 at the 13th position. The mean score for this factor (6.48) is relatively high, which might indicate that a lot of respondents value this factor as important. This score needs however an interpretation with caution since it can also be the result of social desirable answers associated with attitudinal surveys (Gould and Golob, 1998; Kurani et al., 1996).

A.4 Surplus price for environmental friendliness

Consequently, it has been examined if consumers are willing to pay a surplus price for an environmental friendly version of their preferred car. For this purpose the "**Van Westendorp Price Sensitivity Meter"** was used (Socrates technologies, 2005). The theory behind this model is based upon two psychological theories: the "Theory of Reasoned Action" (Fishbein and Ajzen, 1975) and the "Price Signalling Theory" (Spence, 1973). The first theory assumes that consumers can make a rough estimation of the expected cost or cost category of products. The other theory presumes that some low priced products will not be bought, as there are seen as products with poor quality. A disadvantage of the "Price Sensitivity Meter" might be the lack of representing the real purchase behaviour. Two questions have been asked. The first question asked for the respondent's willingness to pay a surplus price for an environmental friendly version of their preferred car (see blue line in Figure 2). In the second question, the respondents had to indicate the maximum amount they were ready to spend on this environmental friendly car (see red line in Figure 2). The first question resulted into a decreasing curve, whereas the second question revealed an increasing curve. The intersection of both curves leads to the **"Point of Marginal Expensiveness" (PME)**. At this point, the amount of respondents that value the surplus price too expensive equals the number of respondents that find the surplus price expensive, but acceptable. In this case, the PME is situated at 1.300 euro. Above this intersection point, the number of respondents that value the surplus price as too expensive will increase. However, it has to be noted that almost 14% of the respondents were not eager to pay an extra amount for an environmental friendly car. This group has not been withheld for the calculation of the PME.

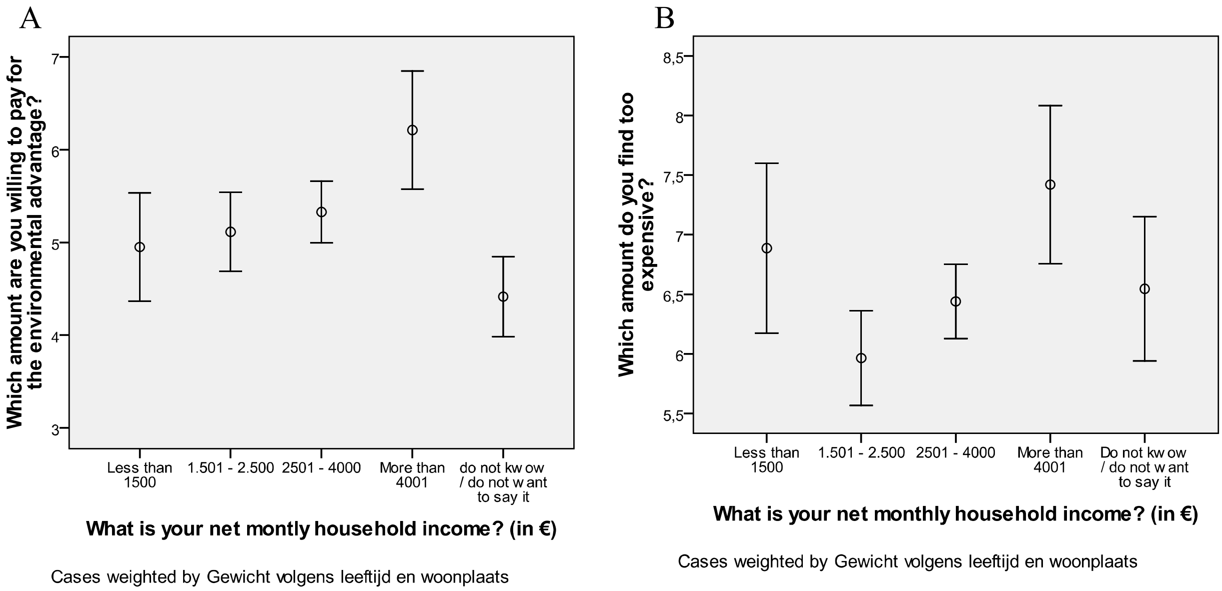
Figure 2: Van Westendorp Price Sensitivity Meter



Source: Own set-up
Blue line: Which net amount are willing to pay for the environmental advantage?
Red line: Which net amount do you find too expensive?

In Figure 3, it has been investigated whether the willingness to pay differs according to the **household income**. Figure 3A displays the amount consumers find acceptable for an environmental friendly version of their preferred car. The lowest mean value is displayed for the group that was not willing to give an indication of their household income. Additionally, the mean value appears to increase along an increasing monthly income. The highest income group displays an average value of 1500 €. In Figure 3B, much more differentiated is noticed regarding the different household income groups. The lowest income group shows an average value of 2000 €, which is the amount that they find too expensive. Surprisingly, the middle income groups display lower mean values of approximately 1500 and 1750 €, which might indicate that lower income groups have a higher willingness to pay an expensive amount for the environmental benefit than middle income classes. The most expensive amount that higher income households are willing to spend is situated around 2250 €. So this might indicate that the lowest and highest income group are willing to pay the largest extra amount for an environmental friendly car, taking into account that these amounts represent a much larger share within the total household income of the lowest income households than in the highest income households. One must however notice that the spread of the results is much higher in these groups, pointing out a larger variation in answers in these two groups.

Figure 3: Willingness to pay according to different income groups



Source: Own set-up

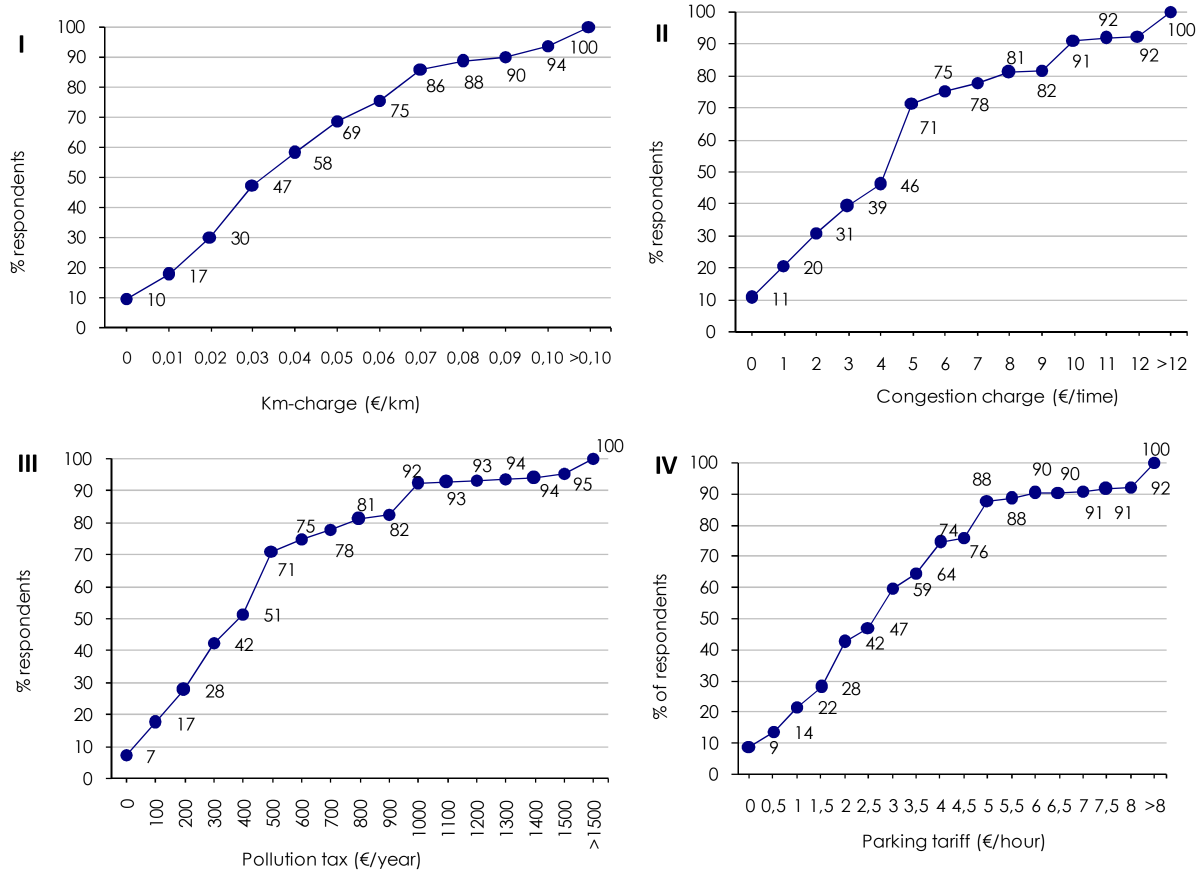
WTP: 3 = 500 € 4 = 750 € 5 = 1000 € 5,5 = 1250 € 6 = 1500 € 6,5 = 1750 € 7 = 2000 € 7,5 = 2250 € 8 = 2500 € 8,5 = 2750 €

A.5 Impact of policy measures

Although the Belgian population shows a heightened concern about the quality of the environment these days, there are not willing to purchase an environmental friendly car even if a reduction of the purchase price for low CO_2 emitting cars and a reduction for diesel cars standard equipped with a particulate filter is granted. The Belgian government could offer these reductions to no more than 43.626[2] cars in 2008. The biggest reduction of 15% could be granted to only 9.637 cars. This is a small amount compared to the 535.947 newly registered cars in 2008. There is however an increasing trend in the purchase of environmental friendly vehicles since the introduction of the reduction for environmental friendly vehicles in 2005. Apart from stimulating the purchase of clean cars by giving reductions, the government can also discourage the purchase and use of energy-inefficient cars by imposing policy measures. Previous research (Peters et al., 2008) demonstrated that a fee at the purchase of a energy-inefficient car has a stronger impact than a reduction of the same amount upon a energy –efficient car as a fee has negative financial implications. In this study, the impact of some policy measures for polluting cars such as (1) **a kilometre charge**, (2) **a congestion charge**, (3) **an increasing parking tariff** and (4) **an extra pollution tax** have been investigated. Consequently, the respondents had to stipulate at which price the policy measure would become so expensive that they would consider the purchase of a cleaner car. Owners of environmental friendly cars would not be affected by these policy measures. Figure 3 shows the buy-response curves. The steepest parts indicate the largest percentual change of the demanded quantity compared to the percentual change of the price (arc elasticity).

[2] Out of these 43.626 cars, the reductions of 3% and 15% were granted to respectively 18.175 and 9.637 cars. The reduction of the purchase for a diesel car, standard equipped with a particulate filter, could be applied to 15.815 cars.

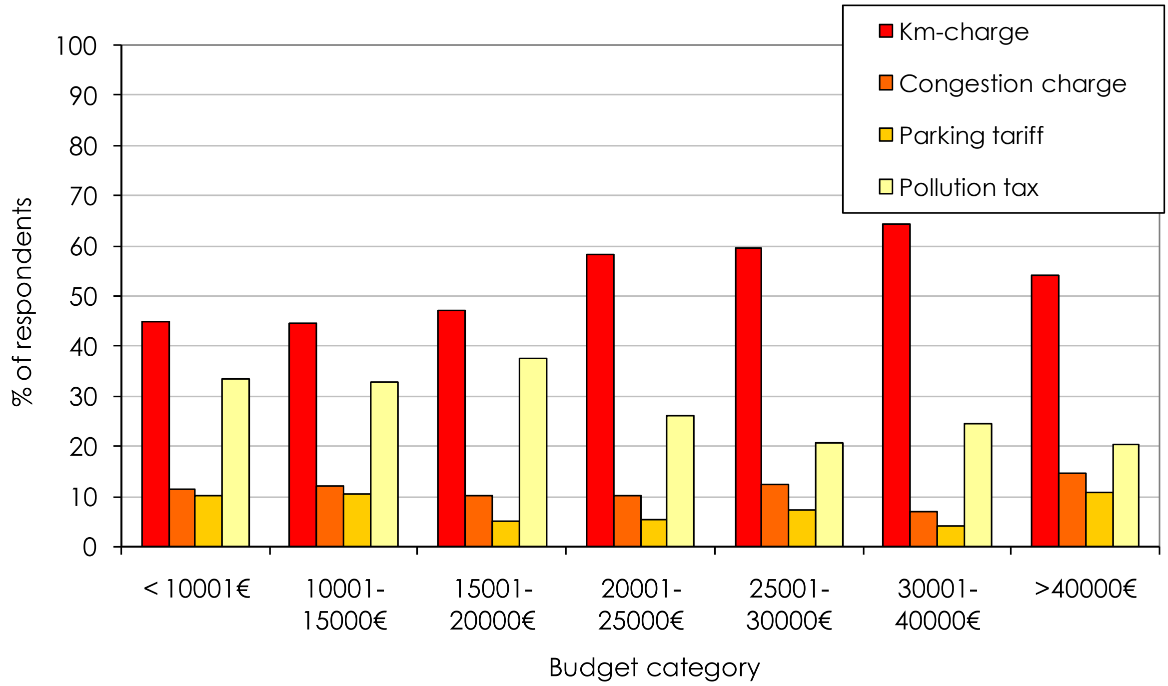
Figure 4: Buy-response curves



Source: Own set-up

For the **kilometre charge** (Figure 4, I), the respondents were asked to precise at which charge/kilometre they would switch to an environmental friendly car. An estimation of this charge on a yearly basis was given, based upon a yearly coverage of 15.000 kilometres. The steepest part is situated between 2 and 3 eurocent/year. This means that a kilometre charge of 2 eurocent/km would stimulate 30% of the respondents to switch to an environmental friendly car, whereas a charge of 3 eurocent/km would already convince 47% of the respondents. A **congestion charge** of 4 euro/time will reach 46% of the respondents (Figure 4, II). At a congestion charge of 5 euro/time, this percentage will increase up to 71%. In case of an **extra pollution tax**, the highest price sensitiveness is situated below 500 euro/year (Figure 4, III). A yearly tax of 300 euro will affect 42% of the respondents, while a yearly tax of 500 euro will have an impact on 71% of the respondents. A **parking tariff** of 3 euro/hour will convince almost 60% of the respondents (Figure 4, IV). At a parking tariff of 4,5 euro/hour, 76% of the respondents would make the shift to an environmental friendly car. A parking tariff of 5 euro would even convince 88% of the respondents. Finally, the respondents had to point out which policy measure would have the largest impact on their purchase behaviour. Out of Figure 5, it seems that a kilometre charge or an extra pollution tax would influence the purchase behaviour the most, independent of the average amount that respondents are ready to spend on the purchase of a new car. In the ideal case, these policy measures should be based on the Ecoscore of the vehicle (Timmermans et al., 2006).

Figure 5: Impact of policy measures



Source: Own set-up

A.6 Conclusion

The results of the face-to-face and web-based survey confirms previous findings demonstrating that the first selection of a new car is based upon the evaluation of rational factors (purchase price, fuel consumption and reliability), whereas the final choice is based on the intrinsic characteristics of the car (comfort, space, size, design) and socio-economic characteristics such as personal, cultural, social and household characteristics. It seems that there is a heightened environmental concern, but which is still of minor importance compared to other car attributes such as reliability, purchase price, security, fuel consumption, comfort, space and size. Moreover, it appears that policy measures such as a kilometre charge or an extra pollution tax can be effective in discouraging the purchase and use of energy-inefficient cars. In the ideal case, these policy measures should be based upon the Ecoscore of cars. This could stimulate the demand for environmental friendly cars evoking a shift in the composition of the Belgian car park towards a more environmental friendly whole.

A.7 References

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B. LITERATURE REVIEW

B.1 Introduction

When evaluating policy measures, it is very important to get an insight in the behavioural responses induced by these governmental incentives. Policy measures will only be effective if they induce the right behavioural changes (Ubbels and Verhoef, 2003). To evaluate the effectiveness of a policy measure, one should take the **travelers'attitudes** (psychological view), as well as the **price elasticities** (economical view) into account. After an introduction to the elasticity concept, this section will consider several factors affecting price sensitivity to research in which direction a price change can influence travel behaviour (psychological view). Next, a literature overview of dissagregated elasticities will be performed with respect to several price components such as vehicle operational costs, parking charges, fuel costs, tolls fees, emissions charges, travel time costs etc. and their resulting changes in travel demand ranging from changes in travel modes, destination, travel routes, departure times and trip patterns to changes of residence and employment location (economical view) (Burris, 2003). Finally, a scheme for the evaluation of policy measures will be presented, developed by Odeck and Brathan (2008). In this scheme, the psychological view (travelers'attitudes) will be linked to the economical view (elasticities) with the aim of getting an insight in the effectiveness of policy proposals. Based on this scheme, recommendations for the use of policy measures in Belgium can be established.

B.2 Elasticities

B.2.1 The elasticity concept

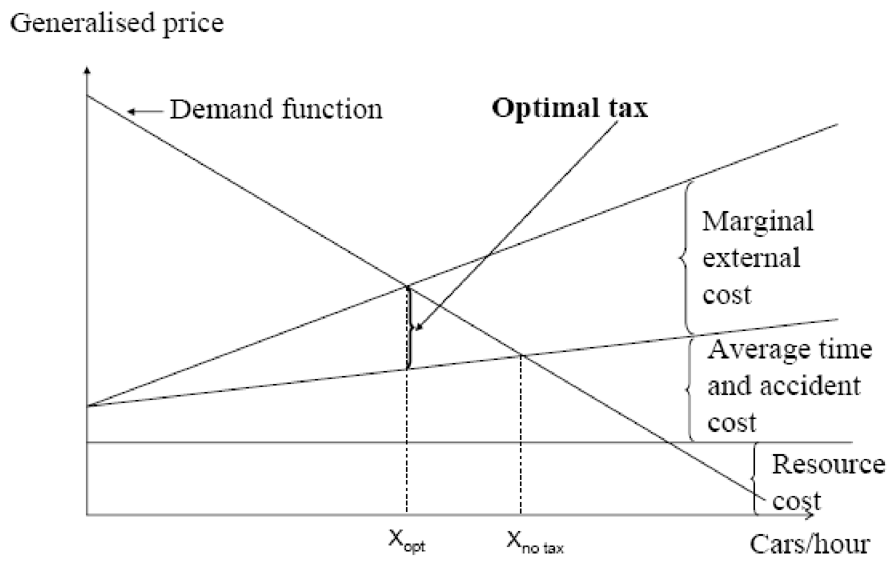
Elasticities are a very important element in the evaluation of policy measures. Car drivers currently base their travel decision upon their **private consumer costs,** including their time and resource costs. However, any individual entering the traffic system will only consider the costs he personally bears (Button, 2003). A car driver will not take the external costs such as accident, congestion and environmental costs into account that he imposes on other road users or the so-called **marginal external costs.** The disparity between the true cost of travelling and the price that drivers are paying is dependent on the price and tax structure.

In Figure 6, it has been assumed that car drivers completely pay for their private consumer costs. The optimal demand for vehicle transport (X_{opt}) is situated at the intersection of the demand curve and the marginal social cost curve. At this point, the price that vehicle users are willing to pay equals the marginal social costs. At $X_{no\ tax}$, the price that vehicle users are willing to pay is lower than the marginal social cost. This current disparity between the true cost of travelling and the price that vehicle users pay leads to an inefficient high travel demand. In theory[3], the optimal flow of traffic would occur if vehicle users are charged an

[3] In practice, it may become difficult to implement policy measures that are closely related to the marginal costs. Due to technical challenges and political objections, there is a strong preference for second-best reasoning, where deviations from the optimal tax scheme are justified (Burris, 2006).

optimal tax. The change in overall price (from private cost to marginal social cost) will evoke a corresponding change in demand (from $X_{no\ tax}$ to X_{opt}). The ratio of these changes is known as the **price elasticity of travel demand** (Mayeres and Proost, 2004; Burris, 2003).

Figure 6: Optimal tax scheme



Source: Mayeres and Proost (2004)

The price elasticity of travel demand measures the reactivity of a change in price on travel demand, both measured in percentage changes (Formule 1). As drivers are a heterogeneous group meaning that every individual driver may react differently to the exact price change when that change occurs in different components of the total driving price, the price elasticity of travel demand in often dissagregated into elasticities with respect to several price components such as vehicle operational costs, parking charges, tolls fees, travel time costs etc. The resulting changes in travel demand are for example changes in travel modes, destination, travel routes, departure times, trip patterns, work schedules, residence, employment location etc. (USEPA, 1998; Burris, 2003).

Formule 1: Price elasticity of travel demand

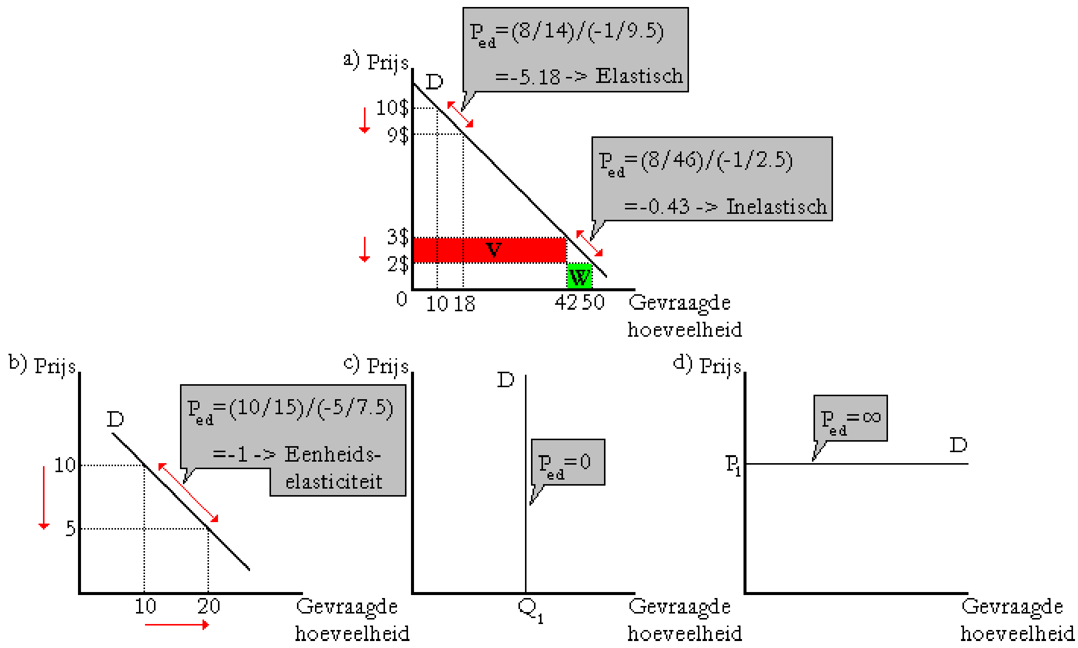
$$elasticity = \frac{\Delta Q}{\Delta P}$$

With:

ΔQ : Percentual change in travel demand
ΔP : Percentual price change

According to the law of demand, price elasticities will always be negative as increasing prices of a certain good or service result into a lower demand of that good or service. The question remains how much the demanded quantity will change as a result of a price change. The demanded quantity is called **elastic** compared to the price change when the absolute value of the elasticity is higher than 1.0. A price change will then result in a more than proportional change of the demanded quantity. The demanded quantity is called **inelastic** compared to the price change when the absolute value of the elasticity is smaller than 1.0. A price change will then result in a less than proportional change of the demanded quantity. An elasticity of 1.0 is called a **unit elasticity** as the demanded quantity will change in exactly the same proportion as the price change. These terms are illustrated in Figure 7.

Figure 7: Elastic – inelastic – unit elastic



Source: Mulhearn et al. (2001)

B.2.2 Measures of elasticity

Several methods can be used to derive price elasticities of travel demand. The first one is the **point elasticity** (Formula 2).

Formula 2: Point elasticity

$$\eta_p = \frac{dQ}{dP} \times \frac{P}{Q}$$

With:

$\frac{dQ}{dP}$ as the partial derivative of the demanded quantity with respect to the price

η_p as the point elasticity

Source: Pratt (2003)

In real world situations, there is often not enough information available to determine the functional relationship between price (P) and demanded quantity (Q). This precludes the calculation of point elasticities from empirical data. As a result, other elasticity measures have been constructed to allow the use of observed changes in price and associated demand. The elasticity measure that most nearly approximates the point elasticity is the frequently used **arc elasticity** (Formula 3)**.**

Formula 3: Arc elasticity

$$\eta = \frac{\Delta \log Q}{\Delta \log P} = \frac{\log Q_2 - \log Q_1}{\log P_2 - \log P_1}$$

With:

Q_1 as the initial demanded quantity before the price change
Q_2 as the final demanded quantity after the price change
P_1 as the original price
P_2 as the new price
η as the elasticity

Source: Pratt (2003)

The arc elasticity is based upon the orginal and final values of demand and price. When one of these values is zero, the **mid-point or linear arc elasticity** (Formula 4) should be used. Except for large price changes of P and Q, this elasticity is a good approximation for the arc elasticity. Mid-point or linear arc elasticities are often used in situations where goods or services become free of charge (f.ex. free public transport).

Formula 4: Mid-point elasticity

$$\eta = \frac{\dfrac{\Delta Q}{(Q_1 + Q_2)/2}}{\dfrac{\Delta P}{(P_1 + P_2)/2}} = \frac{\Delta Q(P_1 + P_2)}{\Delta P(Q_1 + Q_2)} = \frac{(Q_2 - Q_1)(P_1 + P_2)}{(P_2 - P_1)(Q_1 + Q_2)}$$

With:

$\Delta Q = (Q_2 - Q_1)$ expressed in units (number of pieces, etc.)
$\Delta P = (P_2 - P_1)$ expressed in currencies (Euro, Dollar, etc.)

Source: Pratt (2003)

The third and final method is the **shrinkage ratio** or the **shrinkage factor** (Formula 5). This factor is defined as the relative change in demand relative to the original demand divided by the relative change in price relative to the original price.

Formula 5: Shrinkage ratio

$$\eta = \frac{\Delta Q / Q_1}{\Delta P / P_1} = \frac{(Q_2 - Q_1)/Q_1}{(P_2 - P_1)/P_1}$$

With:

$\Delta Q = (Q_2 - Q_1)$ expressed in units (number of pieces, etc.)

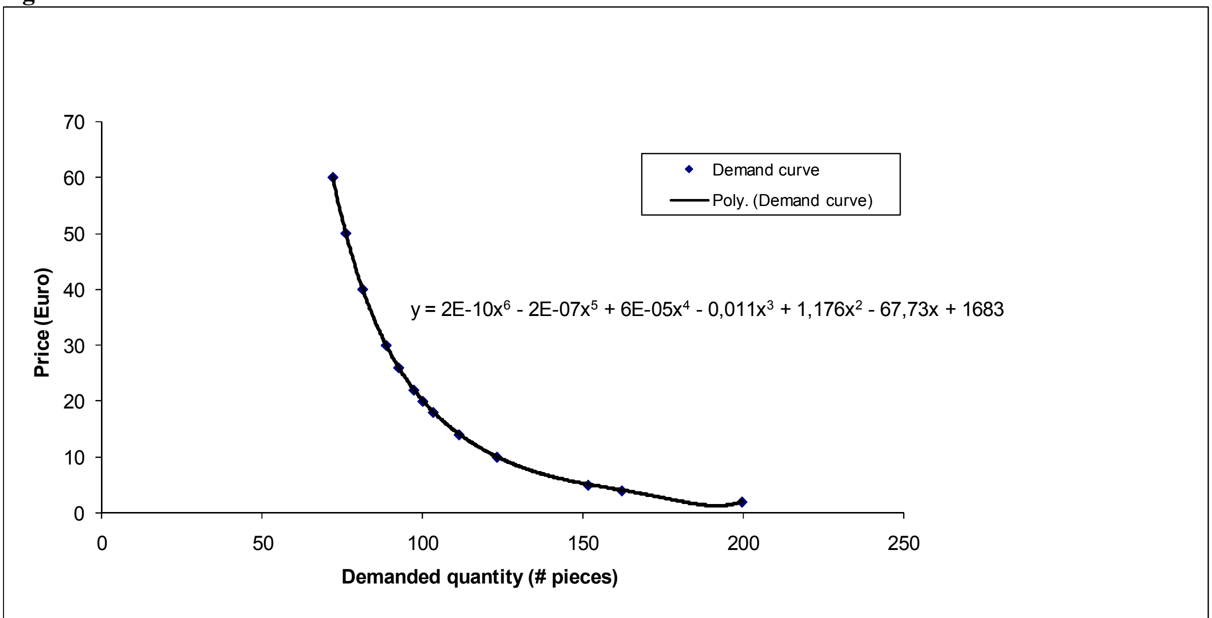
$\Delta P = (P_2 - P_1)$ expressed in currencies (Euro, Dollar, etc.)

Source: Pratt (2003)

B.2.3 Differences between elasticity measures

When the percentage change in price is small, all elasticity measures give approximately the same value (**hypothesis 1**). Large price changes result however in different elasticity values depending on the used elasticity measure (**hypothesis 2).** In this section, these two hypotheses of Pratt (2003) will be tested. Fictive couples of prices and quantities have been used to set up a demand curve (Figure 8, blue points).

Figure 8: Demand curve



Source: David Zimmer (2008)

The first elasticity measure that is tested is the **point elasticity**. As seen in previous section, the functional relationship between P and Q needs to be known to derive point elasticities. The functional relationship has been defined by fitting the couples (P,Q) by a polynoom of order 6 (Figure 8). This polynoom is an approximation of the demand curve. In Table 3, the percentual deviations of the polynoom with respect to the measured couples have been calculated. It has been found that the percentual deviations are smaller than 0,5%, indicating that the polynoom seems to be a good fit of the demand curve. By means of this polynoom, the point elasticities could be derived (Table 4).

Table 3: Fitting the demand curve

Percentual price change	Demand at price P1	Demand at price P2	Original price	New Price	New Price (Polynome approach)	Percentual deviation
%	Q1	Q2	P1	P2		%
	# pieces	# pieces	Euro	Euro		
-90		200		2	2	0,01
-80		162		4	4	0,24
-75		152		5	5	0,39
-50		123		10	10	0,45
-30		111		14	14	0,26
-10		103		18	18	0,18
0	100		20			
10		97		22	22	0,02
30		92		26	26	0,13
50		89		30	30	0,14
100		81		40	40	0,03
150		76		50	50	0,12
200		72		60	60	0,06

Source: David Zimmer (2008)

Table 4: Calculation of the elasticities (2)

Percentual price change	Point elasticity	Arc elasticity	Percentual deviation	Linear arc elasticity	Percentual deviation	shrinkage ratio	Percentual deviation
%			%		%		%
-90	0,041	-0,300	826,35	-0,406	1083,28	-1,106	2777,44
-80	-0,252	-0,300	19,15	-0,355	41,09	-0,776	208,12
-75	-0,319	-0,300	5,88	-0,342	7,19	-0,688	115,72
-50	-0,291	-0,300	2,94	-0,311	6,64	-0,462	58,62
-30	-0,298	-0,300	0,83	-0,303	1,80	-0,376	26,52
-10	-0,302	-0,300	0,77	-0,300	0,68	-0,321	6,22
0	-0,303						
10	-0,303	-0,300	0,94	-0,300	0,88	-0,282	6,93
30	-0,301	-0,300	0,48	-0,302	0,04	-0,252	16,30
50	-0,300	-0,300	0,10	-0,304	1,34	-0,229	23,57
100	-0,298	-0,300	0,75	-0,311	4,37	-0,188	36,95
150	-0,300	-0,300	0,06	-0,319	6,17	-0,160	46,62
200	-0,306	-0,300	1,92	-0,327	6,79	-0,140	54,10

Source: David Zimmer (2008)

In real world situations, lack of information on the functional relationship between P and Q precludes the calculation of point elasticities from empirical data. For that reason, other elasticity measures have been used to measure the observed price changes and associated demand such as the arc elasticity, the linear arc elasticity and the shrinkage ratio (Table 4). Out of table 4, it seems that these elasticity measures are less accurate than the point elasticity, as shown by their percentual deviations. These deviations prove that the arc elasticity is the best approximation of the point elasticity. The extreme values in the first row of Table 4, are due to the fact that the polynoom shows an increasing trend at the end which leads to positive elasticities (Figure 8). Table 4 also points out some irrigularities with respect to the shrinkage ratio. Its elasticities are not the same at increasing and decreasing prices, in contrast the arc elasticity. In Table 5, the calculated elasticities are used to calculate the new demanded quantities Q2. In order to get an adequate comparison of the different elasticity measures, the point elasticity has been kept at a constant elasticity rate of -0,3.

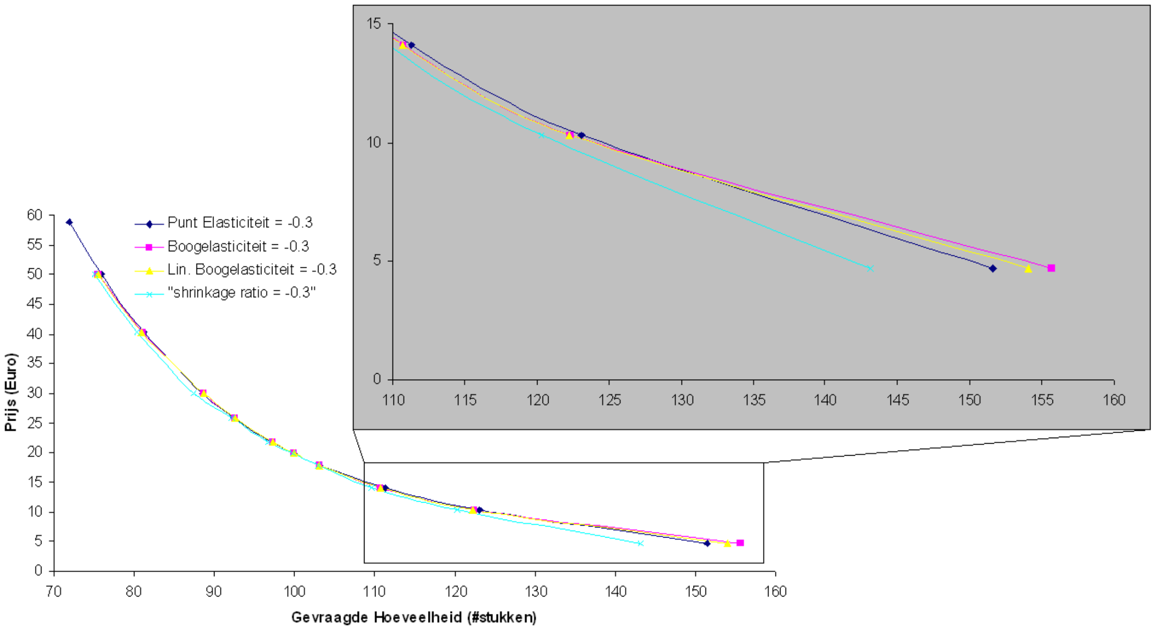
Table 5: Elasticity methods for small price intervals

Demand at P1	Original price	Point elasticity	Arc elasticity = -0.3		Linear arc elasticity = -0.3	shrinkage ratio = -0.3	
Q1	P1		P2	Q2	P2	P2	Q2
# pieces	Euro		Euro	# pieces	Euro	Euro	# pieces
152	5	-0,300					
123	10	-0,300	5	156	5	5	143
111	14	-0,300	10	122	10	10	120
103	18	-0,300	14	111	14	14	110
100	20	-0,300	18	103	18	18	103
97	22	-0,300	20	100	20	20	100
92	26	-0,300	22	97	22	22	97
89	30	-0,300	26	93	26	26	92
81	40	-0,300	30	89	30	30	87
76	50	-0,300	40	81	40	40	80
72	59	-0,300	50	76	50	50	75

Source: David Zimmer (2008)

Table 5 confirms **hypothesis 1** illustrating equivalent results (Q2) for all elasticity measures at small percentual price changes. One exception is the shrinkage ratio showing a larger deviation. This underlines the supposition that the shrinkage ratio is seen as the less suitable approach (Pratt, 2003). In Figure 9, the results are presented graphically.

Figure 9: Demand curves for small price intervals



Source: David Zimmer (2008)

In order to test **hypothesis 2** pretending that large price changes result into significant differences along the elasticity measure, the demanded quantities (Q2) associated with large price changes have been calculated (Table 6).

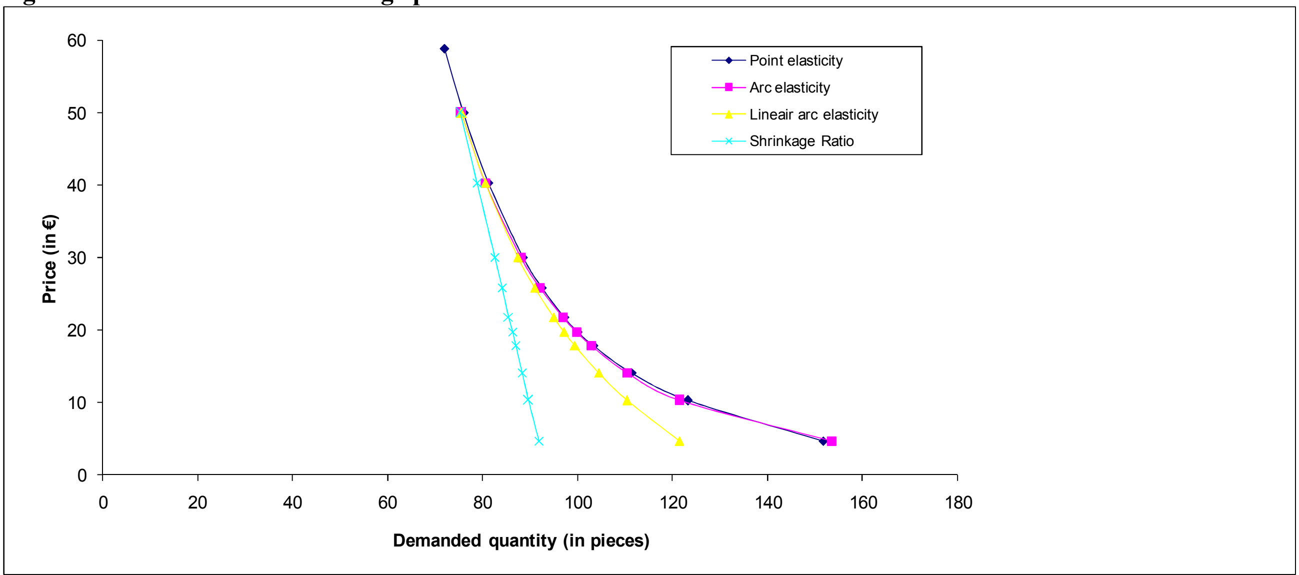
Table 6: Elasticity methods for large price intervals

Demand at P1	Original price	Orginal demand at price P2	Point elasticity	Arc elasticity = -0.3		Linear arc elasticity = -0.3		shrinkage ratio = -0.3	
Q1	P1	Q1(P2)		P2	Q2	P2	Q1	P2	Q1
# pieces	Euro	# pieces		Euro	# pieces	Euro	# pieces	Euro	# pieces
72	59								
72	59	152	-0,300	5	153	5	121	5	92
72	59	123	-0,300	10	121	10	110	10	90
72	59	111	-0,300	14	110	14	104	14	88
72	59	103	-0,300	18	103	18	99	18	87
72	59	100	-0,300	20	100	20	97	20	86
72	59	97	-0,300	22	97	22	95	22	86
72	59	92	-0,300	26	92	26	91	26	84
72	59	89	-0,300	30	88	30	87	30	82
72	59	81	-0,300	40	81	40	80	40	79
72	59	76	-0,300	50	76	50	76	50	75

Source: David Zimmer (2008)

The greater the price change, the greater the elasticity measures differ from the point elasticity. This confirms hypothesis 2. The results are presented graphically in Figure 10.

Figure 10: Demand curves for large price intervals



Source: David Zimmer (2008)

B.3 Factors affecting price sensitivity

In this section, several factors affecting price sensitivity will be identified as it is interesting to determine in which direction a price change can influence travel demand. The identified factors are among others type of price change, characteristics of the pricing policy, type of trip and traveller, quality and price of alternative routes, modes and destinations, scale and scope of pricing and time period.

B.3.1 Type of price change

Different policy measures can have various impacts on travel behaviour (Table 7). **Fixed vehicle taxes** will affect vehicle ownership and vehicle type as the price of car ownership will increase. **Fuel prices** affect vehicle use and causes travellers to switch modes, take shorter trips or change destinations. A fuel price increase seems to affect longer trips more than shorter trips due to the direct proportion of vehicle kilometres travelled. Higher fuel prices also stimulate less rapid acceleration, better maintenance, and other driving-style improvements to reduce fuel consumption. On the longer term, vehicle ownership will also be affected as people will purchase more fuel-efficient vehicles (USEPA, 1998). **Fixed tolls and congestion pricing** will rather affect car use and can induce a destination change, fewer trips and stimulate the use of other modes such as public transportation. **Parking fees** are more likely to affect vehicle ownership, but they have also an impact on trip destinations as well as on vehicle use as the fee has an explicit linkage to the particular trip (USEPA, 1998). **Subsidies** are rather seen as a supportive strategy of another active pricing measure as travel behaviour is less influenced by a cost incentive than a disincentive (USEPA, 1998). This is confirmed by Peters et al. (2008) saying that the improved fuel efficiency of a combination of a rebate for a fuel- efficient car and a fee for a fuel-inefficient car comes from only 5% by consumers choosing other makes, models and classes of vehicles whereas 95% of the improved fuel economy comes through manufacturers. In case of **modal subsidies** increasing the use of less-polluting modes through a reduction in their relative price, small land use effects are expected unless the subsidies are of significant size and permanent. It would also have a large impact on the modal shift as the modes being subsidized become very attractive. **Emission fees** can be designed in several ways. It can be added to the vehicle registration tax and/or circulation tax discouraging vehicle ownership of older and higher-emitting vehicles. Another option is to link the emission fee to the annual travelled vehicle kilometres or by relating it to the actual measured emissions at the time of inspection. In that case, vehicle ownership as well as vehicle use will be affected (USEPA, 1998).

Table 7: Impacts of Different Types of Pricing

Type of Impacts	Vehicle Fees	Fuel Price	Fixed Toll	Congestion Pricing	Parking Fee	Modal Subsidies	Emission Fees
Vehicle ownership. Consumers change the number of vehicles they own.	X				X	X	X
Vehicle type. Motorist chooses different vehicle (more fuel efficient, alternative fuel, etc.)	X	X					X
Route Change. Traveler shifts travel route.			X	X	X		X
Time Change. Motorist shifts trip to off-peak periods.				X	X		
Mode Shift. Traveler shifts to another mode.		X	X	X	X	X	
Destination Change. Motorist shifts trip to alternative destination.		X	X	X	X		X
Trip Generation. People take fewer total trips (including consolidating trips).		X	X	X	X	X	X
Land use changes. Changes in location decisions, such as where to live and work.			X		X	X	X

Source: Litman (2008) and USEPA (1998)

B.3.2 Characteristics of the pricing policy

Policy measures are only effective if they are accepted by the public. It appears that people accept policy measures if they believe that it will not be effective and vice versa (Steg, 2003). Two major factors affect the effectiveness and acceptability of policy measures. The first factor is associated with the individual characteristics. The second factor is related to the exact shape of the policy measure. The shape of the policy measure depends on four items (1) static, dynamic or variable, (2) push or pull, (3) size of price change and (4) terms of payment.

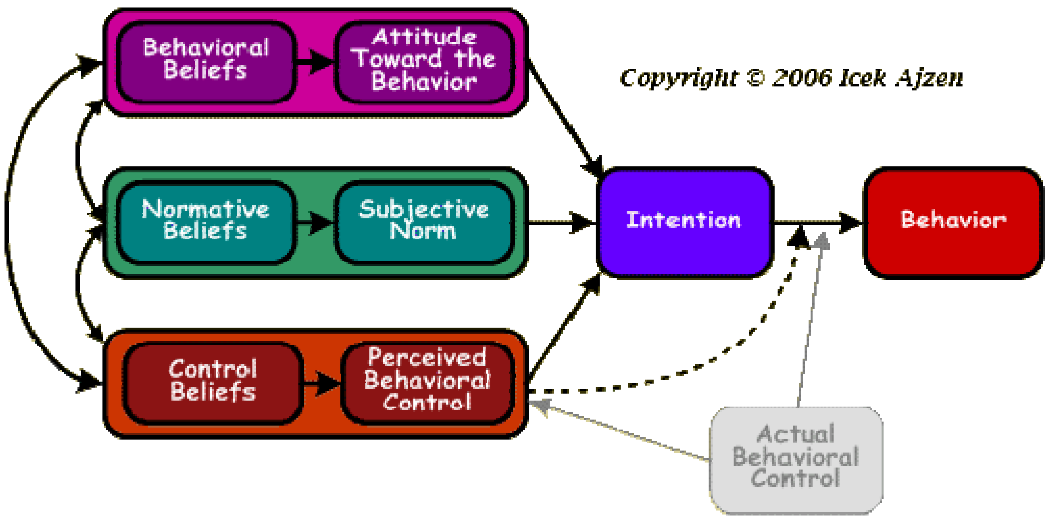
B.3.2.1 Static, Dynamic or Variable policy

Static policy is not differentiated to time, location and type of vehicle. This kind of policy counts for everyone at anytime, anywhere and for any type of vehicle. **Dynamic** policy takes the current traffic situation into account and bases its price dependent on the traffic situation at a certain time. **Variable** policy is the most commonly used policy and it targets specific user groups, roads, vehicle types, time periods etc. (Schuitema, 2003).

B.3.2.2 Push or pull measures

Push measures intent to make car ownership and usage less attractive (f.ex. increasing vehicle costs). This kind of measures is seen as a punishment as they involve negative financial implications. **Pull measures** have in contrast no direct influence on car use (f.ex. stimulating the use of alternative transportation modes). This kind of measures is seen as a reward and offers people more opportunities. The **acceptability** of push or pull measures depends on several factors (Eriksson et al., 2008). A first factor is how the **revenues** will be spend. Road users prefer schemes where the additional receipts are used in the same domain than using it for general public funds. Politicians prefer budgetary neutral proposals keeping the total tax receipts constant. A second factor is the **perceived effectiveness**. The acceptability will be higher when the policy measure is perceived to actually contribute to f.ex. the solution of environmental problems. A third factor is the extent in which the measure is perceived to be **fair**. A final factor is the **individual characteristics** such as intentions shaped by attitudes, subjective norms and perceived behavioural control (Figure 11). Attitudes are the extent in which on assesses something favourable or not favourable. Subjective norm is the perception of a person about the normative expectations of others such as close friends or family. Perceived behavioural control is the personal feeling that one could easily change its behaviour and that one disposes over possibilities to do this. The actual behaviour will be based upon intentions, determined by attitudes, subjective norms and perceived behavioural control. This Theory of Planned Behaviour pretends that if attitudes and subjective norms are favourable, the perceived behavioural control will be larger and the intention for behavioural change will be stronger (Ajzen 1985; Ajzen 1991). In this respect, policy measures will be acceptable if one has a negative attitude towards car use, one does not experience a strong social pressure for car use, and when one has the feeling of being able to change his behaviour (Steg and Schuitema, 2003).

Figure 11: Theory of planned behaviour



Source: Ajzen, 2006

B.3.2.3 Size of the price change

The size of the price change plays a very important role in evaluating policy measures. **Small price changes** evoke only minor effects as these price changes are often not observed. **Large price changes** are in contrast more effective in evoking behavioural changes. In general, large price changes are perceived as less acceptable than small price changes (Steg, 2003). This is first of all related to the fairness of the measure. Secondly, large price changes can evoke reactance as it could restrict the financial freedom of people. Large price changes are nevertheless more effective in changing travel behaviour, as long as it is found acceptable by the public. Price reductions will only be effective if related to large price reductions (Linderhof, 2001). Price reductions are often used to make alternative transportation modes more attractive. Small as well as large price reductions are acceptable as they imply no financial consequences (Schuitema, 2003).

B.3.2.4 Terms of payment

The **shorter** the payment period, the more effective the policy measure. Payments can be done directly or later on. Excises on fuel are for example paid directly, whereas taxes related to car ownership are paid later on. Such fixes taxes have no influence on car use as they are associated with car ownership. Price changes on the **long term** will rather influence the behaviour on the long term (with respect to car ownership), than on the short term (with respect to car use). Variable taxes such as excises on fuel can affect long term as well as short term behaviour. As a result, variable taxes can influence more types of behaviour than fixed taxes (Schuitema, 2003).

B.3.3 Type of trip and traveller

Commuting trips tend to be less elastic than other trips. At increasing car costs, **shopping and visiting trips** will be most affected, while commuting trips will be less affected (Schuitema et al., 2007). **High income travellers** tend to be less price sensitive than **low income travellers**. Some demographic groups such as people with lower incomes, people without a driver's licence, students, disabled persons or elderly people appear to be more dependent on public transportation. As a result, price changes will only have minor effects on the use of public transportation. If the transit system wants to attract more people while reducing car use, transit prices will have to go down meanwhile improving the supplied services in order to attract more price sensitive discretionary travellers (Litman, 2004). **Big cities** tend to have lower elasticity values than the **suburbs** as they have a larger amount of transit dependent users. The bigger the city, the larger the use of public transportation. This is the result of the increasing traffic congestion, parking tariffs and better transit services (Litman, 2004).

B.3.4 Quality and price of alternative routes, modes and destinations

There is a higher price elasticity if **alternative routes, modes and destinations** are of good quality and affordable. A tolled highway is for example more price elastic when there exists a parallel untolled highway (Litman, 2008).

B.3.5 Scale and scope of pricing

Peak-period travelling on a certain road can be price elastic as this may shift travelling to alternative routes, destinations, modes and travel times. Most policy measures (tolls, parking charges, fuel taxes) will be price inelastic as these extra costs represent a small share within the total user costs of a car. Driving is however elastic when the total costs of the car are taken into account. If fuel costs make up 15% of the total costs of the car, its elasticity of -0,2 will actually be an elasticity of -1,3 if one takes into account the total financial costs (Litman, 2008).

B.3.6 Time period

Transportation elasticities tend to increase over time as consumers will take prices into account when making long-term decisions (Figure 12). That is why it can take some time before the full effect of the price change appears. **Short-term elasticities** are usually defined as responses made within less than two years, whereas **long-term elasticities** are rather related to periods of 5 to 10 years, within which the greatest part of the response is in the first 3 to 5 years. Long-run elasticities are estimated to be larger, usually by a factor 2 to 3, than short-run elasticities (Goodwin, Dargay and Hanley, 2003).

Figure 12: Dynamic elasticity

Source: Dargay and Hanly in: Litman, 2004

B.3.7 Comparing distant places and times

Price changes seem to have similar effects in **distant places and time**. As a result, it may be appropriate to evaluate a policy measure relative to the local wages or incomes, so that the results can be compared between different countries and time periods (Litman, 2008). Extra care should be given to forecasting the value of a price in a future year as it is commonly assumed that all travel prices will increase in the future at the same rate of inflation. Moreover, it is extremely difficult to extrapolate results from other parts of the world to particular environments as it depends on several variables such as congestion levels, quality of alternative modes, political climate, level of public engagement in transportation planning and pricing levels (Washbrook et al., 2006).

B.3.8 Large and cumulative price changes

Extra care should be used when calculating the impacts of large price changes or when summing the effects of multiple changes, because each subsequent change impacts a different base (Litman, 2008).

B.4 Literature review

As there exists no single elasticity of policy measures, the price elasticity is often disaggregated into elasticities with respect to several price components such as vehicle operational costs, parking charges, fuel costs, tolls fees, emission charges, travel time costs etc. This literature overview will consider those disaggregated elasticities and will give an overview of resulting changes in travel demand ranging from changes in travel modes, destination, travel routes, departure times and trip patterns to changes of residence and employment location (USEPA, 1998; Burris, 2003).

B.4.1 Vehicle operating costs

This elasticity measures the effect of **vehicle operating costs** such as fuel costs, parking charges etc. on travel demand. De Borger et al. (1997) estimated elasticities for urban peak travel in Belgium to be – 0,384 for vehicles and – 0, 35 for public transit. As a 10% increase in price will result in a decreasing demand of 3,8% for vehicle travel, and 3,5% for public transit, we may conclude that the Belgian consumer is on average more sensitive for its vehicle expenses than for its public transport expenses. As to Small and Winston (1999), the price sensitivity of a particular vehicle's use increases over time depending on whether it is the only vehicle in the household or not. This may be important when analyzing the impact policy measures can have on the use of vehicles that have desirable attributes such as increased fuel efficiency or reduced emissions (Litman, 2008). Table 8 illustrates the impact of out-of-pocket expenses on travel demand. Leisure activities display the largest elasticities because of the availability of various alternatives.

Table 8: Elasticities with respect to out-of-pocket expenses

Type of trip	Elasticity of road travel w.r.t. out of pocket expenses
Urban shopping	-2.7 to -3.2
Urban commuting	-0.3 to -2.9
Inter-urban business	-0.7 to -2.9
Inter-urban leisure	-0.6 to -2.1

Source: Button (1993) in: Litman (2008)

B.4.2 Parking price

Vehicle drivers tend to be very sensitive to parking prices as they have to be paid immediately (Litman, 2008). Parking prices are found to have a larger effect on vehicle trips, 1.5 to 2 times larger, than other out-of-pocket expenses (USEPA, 1998). Table 9 displays the impact parking prices may have on various types of travel. The displayed elasticities are **European long-term elasticities** for vehicle-oriented urban areas and they refer to increasing parking rates in areas where parking charges already exist.

Table 9: European parking price elasticities

Purpose	Car Driver	Car Passenger	Public Transport	Slow Modes
Trips				(Walking or cycling)
Commuting	-0.08	+0.02	+0.02	+0.02
Business	-0.02	+0.01	+0.01	+0.01
Education	-0.10	+0.00	+0.00	+0.00
Other	-0.30	+0.04	+0.04	+0.05
Total	***-0.16***	***+0.03***	***+0.02***	***+0.03***
Kilometres				
Commuting	-0.04	+0.01	+0.01	+0.02
Business	-0.03	+0.01	+0.00	+0.01
Education	-0.02	+0.00	+0.00	+0.00
Other	-0.15	+0.03	+0.02	+0.05
Total	***-0.07***	***+0.02***	***+0.01***	***+0.03***

Source: TRACE (1999) in: Litman (2008)

A 10% increase in parking charges will decrease car drivers' trips with - 1,6% and car drivers' kilometres with - 0,7%. Increasing parking prices will in contrast stimulate carpooling: + 0,3% for trips and + 0,2% for kilometres. Alternative transportation modes such as public transport and slow modes will also become more attractive. According to TRACE (1999), parking price elasticities can also be used to predict the impact of an area or cordon- based road pricing or to predict the impact of a change in supply of parking spaces as the price is more or less a fixed amount per trip. With respect to **parking supply**, Mildner, Stratman and Bianco (1997) discovered that increased supply tends to increase vehicle use, while reducing the use of public transport and carpooling. A higher parking charge will also have a negative impact on the use of **parking facilities** within a certain area. A decrease in use of parking facilities in one area can result in an increase of the use of parking facilities in other areas without higher parking fees. Another possible effect of higher parking charges in one area is illegitimate "spillover" parking.

Total vehicle travel can be affected by increasing parking charges on the condition that there is an effective enforcement of **parking regulations** and an availability of good travel alternatives. However, Mayeres and Proost (2004) discovered that one could obtain only 30% of welfare gain (with respect to the optimal policy) by imposing parking charges in Belgium. This low amount of welfare gain is due to the fact that parking charges cannot be differentiated according to off-peak and peak periods.

As most parking is free outside the commercial areas of Belgium, it is interesting to have a look at the effect from **free to priced parking** on mode shifts (drive alone, carpool, transit and other). Feeney (1989) (in: Litman, 2008) found out that shifting from free to priced parking reduces drive alone commuting by 10-30%, especially in combination with improvements in transit service. A last interesting result comes from Washbrook, Haider and Jaccard (2006) where it was determined how commuters respond to various pricing measures such as a road toll and a parking charge and how it would affect their drive alone rates. Table 10 shows that free parking, combined with unpriced roads results into 83% commuters driving alone. A parking fee of $3, together with a daily road toll of $3 results in 56% of the commuters driving alone. A parking fee of $9 and a road toll of $9 will reduce the commuters driving alone to 17%, which is a reduction of 66% in drive alone demand compared to the first "free" scenario.

Table 10: Impact of various pricing measures on commuting

Road Toll	Free Parking	$1 Parking	$3 Parking	$6 Parking	$9 Parking
$0	83%	80%	74%	62%	49%
$1	78%	75%	68%	55%	42%
$3	68%	65%	56%	43%	30%
$6	56%	52%	43%	31%	21%
$9	50%	46%	37%	26%	17%

Source: Washbrook, Haider and Jaccard (2006) in: Litman (2008)

B.4.3 Fuel consumption with respect to fuel price

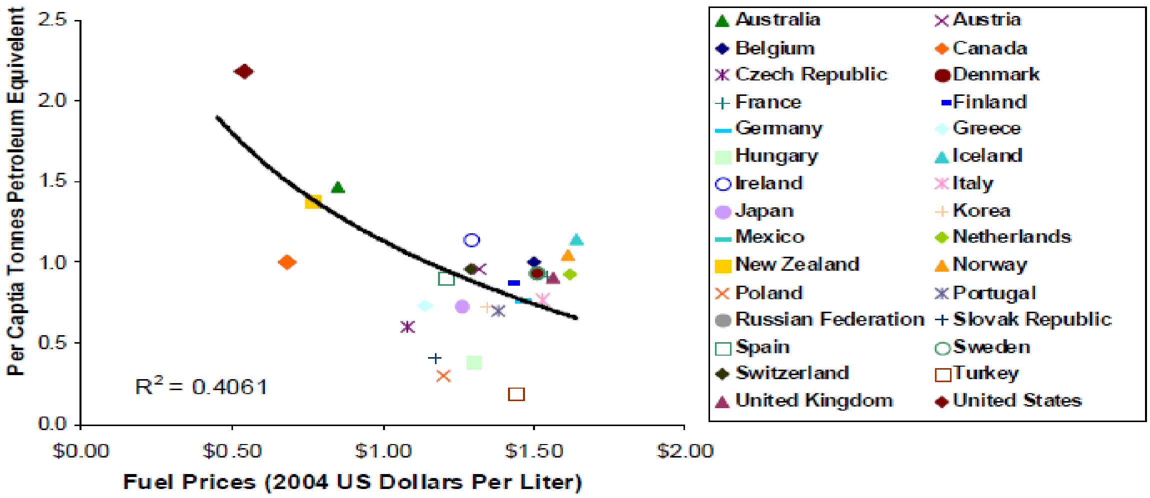
Fuel price elasticities are one of the most widely studied elasticities. A review of **fuel price elasticities**, elaborated by Goodwin (1992) resulted in a short-run fuel price elasticity of – 0, 27 and a long-run fuel price elasticity of – 0,71. In the short run, a 10% increase in fuel prices will reduce fuel consumption with 2,7% as total vehicle travel and traffic speeds will decrease. The reduction in total vehicle travel is estimated to be – 1,5%. In the longer run, a 10% increase in fuel prices will reduce fuel consumption by 7% as people will switch to the purchase of more fuel-efficient vehicles and to more accessible land use patterns. Moreover, total vehicle travel tends to decrease with 3 to 5%. Short term as well as long term elasticities are higher for fuel consumption than for vehicle traffic as the rapid behavioural responses such as changes in driving speed or style, or modifying the least energy-inefficient trips will affect fuel consumption more than traffic. Manipulation of fuel prices will in this respect be more effective in reducing fuel consumption than in reducing road congestion (Graham and Glaiser, 2002). In addition, fuel taxes will reduce the overall long-term fuel consumption much more than an increase in other vehicle related taxes such as ownership taxes (Johansson and Schipper, 1997).

In the **short run**, fuel prices will affect **traffic speed**. Traffic speed is dependent on the height of fuel price change, the potential fuel savings and the drivers'value of time. CBO (2008) discovered that if the value of potential fuel savings is small compared to the value of time, the likely effect of fuel prices on traffic speed will be rather small. Car drivers will reduce their speed up to the level at which the value of the fuel savings equals the value of time lost to slower driving. It has to be noticed that the preferred speed is of course also a function of other variables such as the local speed limit and its enforcement, time of the day, time of the year, traffic density, and physical characteristics of the road and location. The effect of fuel prices on traffic speed has been estimated to be around -0,05 indicating that a 10% increase in the price of fuel would cause the median speed to decrease by about 0,5%.

The longer fuel prices remain, the more it will affect the consumers' expectations about future prices. These expectations will influence the consumers **long-term** decisions such as the purchase of a new car. CBO (2008) warns for the fact that a smaller fuel price effect may be expected as automakers are giving incentives in times of higher fuel prices for cars with a higher fuel consumption such as SUVs and light trucks. As a result, consumers will be stimulated to purchase a fuel-inefficient car in times of high fuel prices.

Figure 13 shows that countries with higher fuel prices tend to drive with more fuel-efficient vehicles (**long-term effect**), driving fewer annual kilometres and rely more on alternative modes (**short-term effects**). The United States, Canada, Australia and New Zealand are for example experiencing low fuel prices which results into a high transport energy consumption. Other countries with higher fuel prices consume about half as much transport energy. Moreover, Lutsey and Sperling (2005) found out that countries with low fuel prices use vehicle energy efficiency improvements to increase the vehicle performance rather than improving the fuel economy.

Figure 13: Fuel price versus per capita Transport Energy Consumption



Source: Litman (2007)

A very interesting result comes from Small and Van Dender (2007) and CBO (2008) pointing out that household **income** appears to have a larger impact on fuel consumption than fuel prices. In addition, the impact of fuel prices on driving and on the demand for fuel appears to decline as income rises. A consequence is that the impact of fuel prices on fuel demand works increasingly through economy improvements rather than through reductions in the amount of driving. As a result, fuel taxes should rise more than income to keep fuel consumption at a constant rate. High fuel taxes are however not politically attractive. That is why Small and Van Dender (2007) advise to combine fuel taxes with **fuel-efficiency regulations**. Improved fuel-efficiency may in contrast produce a "rebound effect", as a better fuel economy will result in lower fuel costs and in increased driving. This rebound effect is expected to be rather small thanks to two reasons. The first one is that rising incomes will diminish the rebound effect as the share of fuel expenditures within the total expenditures will decline, which might lead to lower elasticities. The second one is that higher incomes lead to higher values of time so that time costs become relatively more important than fuel costs. Taking into account this small rebound effect, Small and Dender (2007) are in favour of combining fuel taxes with fuel-efficiency regulations as it would promote technological improvements whilst evoking vehicle-mix shifts towards more fuel-efficient vehicles. Another motivation for fuel-efficiency regulations is that there are **imperfections** in the market for vehicles that are not sufficiently dealt with by fuel taxes alone. There are several indications that consumers tend to underinvest in fuel economy (Joint Transport Research Centre, 2008). Reasons for these market imperfections are the insufficient information at the point of purchase on the trade-off between more expensive technologies and lower fuel costs, frictions in markets for used cars, the fact that drivers pay little attention to fuel economy as there care more about other attributes and the share of fuel costs in the total purchase and use costs is small, inappropriate incentives in company car markets, and uncertainty for manufacturers about the reactions of car buyers and competing manufacturers to produce more efficient, but more expensive vehicles. These frictions may justify interventions such as providing better information and regulating fuel economy.

Goodwin, Dargay and Hanly (2004) define the **elasticity of fuel efficiency** a combination of the elasticity of fuel consumption and the elasticity of vehicle-kilometres (Formula 6).

Formula 6: Elasticity of fuel efficiency

Elasticity of fuel efficiency = - elasticity of fuel consumption + elasticity of vehicle-km

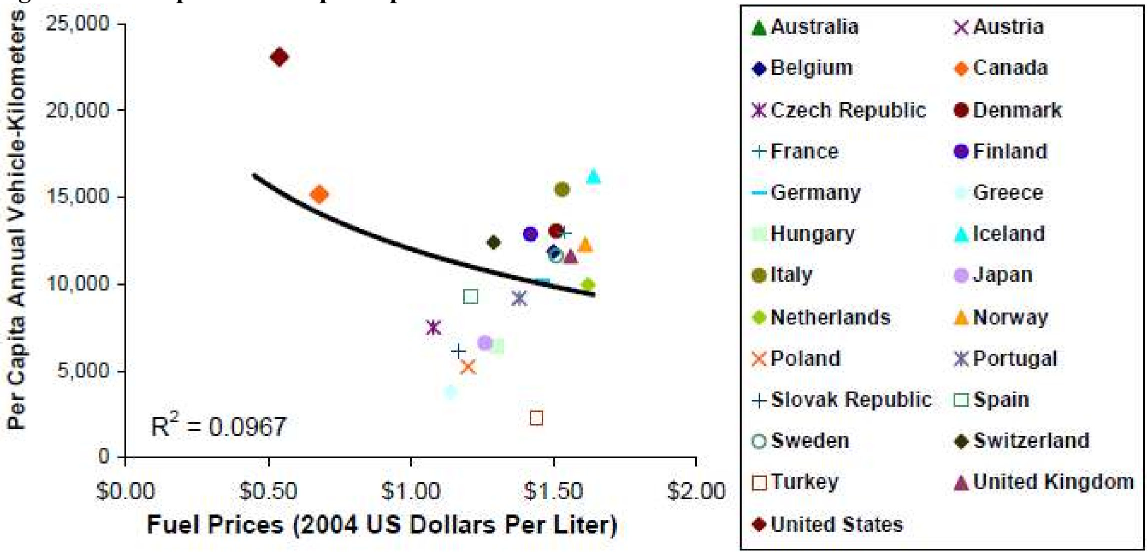
Source: Goodwin, Dargay and Hanly (2004)

Early research (Baltagi and Griffin, 1983) found out that the elasticity of fuel efficiency with respect to fuel price is situated between – 0,6 and -0,9, meaning that a 10% increase in fuel price will reduce the fuel inefficiency by 6 to 9%. As said by Espey (1996), one needs to take the pure technological improvements in fuel economy into account when estimating short and long run impacts. She assumed an annual increase in fuel efficiency of 2,8%, independent from changes in fuel prices and income. Moreover, this author believes that changes in the **registration and circulation taxes** of vehicles may have important effects on fuel efficiency.

B.4.4 Vehicle travel with respect to fuel price

About a third of fuel savings resulting from an increase in fuel prices consist of reductions in **vehicle mileage**. Figure 14 demonstrates how changes in fuel prices affect the per capita annual vehicle-kilometres. One can see that the per capita vehicle-kilometres decrease in countries with high fuel prices.

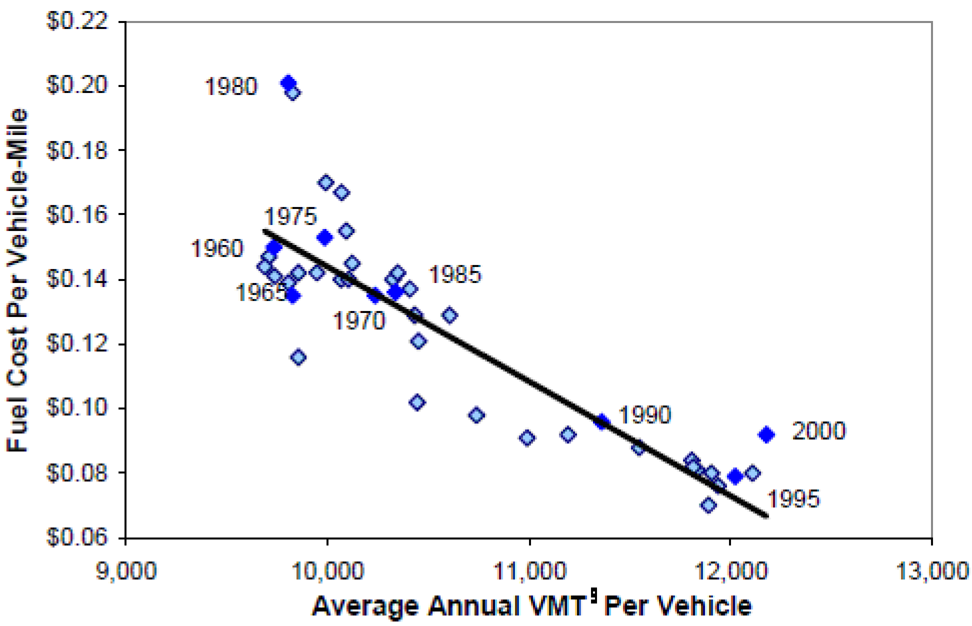
Figure 14: Fuel price versus per capita Vehicle Travel



Source: Litman (2007)

Figure 15 demonstrates how changes in real fuel prices affect the per capita annual vehicle mileage. The annual vehicle mileage increases at declining real fuel costs per kilometre. Schimek (1997) estimated the elasticity of vehicle travel with respect to the fuel price to be -0,26, indicating that a 10% increase in fuel prices will decrease vehicle travel with 2,6%. Goodwin, Dargay and Hanly (2004) compared the effect of a fuel price increase on **fuel consumption** and **vehicle travel**. They observed higher elasticities for fuel consumption than for vehicle travel. A fuel price increase will thus rather stimulate car drivers to reduce their fuel consumption than to reduce their vehicle mileage. Fuel consumption can be reduced by changing the driving style, shifting the pattern of journeys so that more of them are in a fuel – efficient context and finally by changing to more fuel-efficient vehicles (see previous section).

Figure 15: Fuel price versus Annual Vehicle Mileage



Source: BTS (2001) in Litman (2008

Table 11: European elasticities with respect to fuel price

Purpose	Car Driver	Car Passenger	Public Transport	Slow Modes
Trips				
Commuting	-0.11	+0.19	+0.20	+0.18
Business	-0.04	+0.21	+0.24	+0.19
Education	-0.18	+0.00	+0.01	+0.01
Other	-0.25	+0.15	+0.15	+0.14
Total	***-0.19***	***+0.16***	***+0.13***	***+0.13***
Kilometres				
Commuting	-0.20	+0.20	+0.22	+0.19
Business	-0.22	+0.05	+0.05	+0.04
Education	-0.32	+0.00	+0.00	+0.01
Other	-0.44	+0.15	+0.18	+0.16
Total	***-0.29***	***+0.15***	***+0.14***	***+0.13***

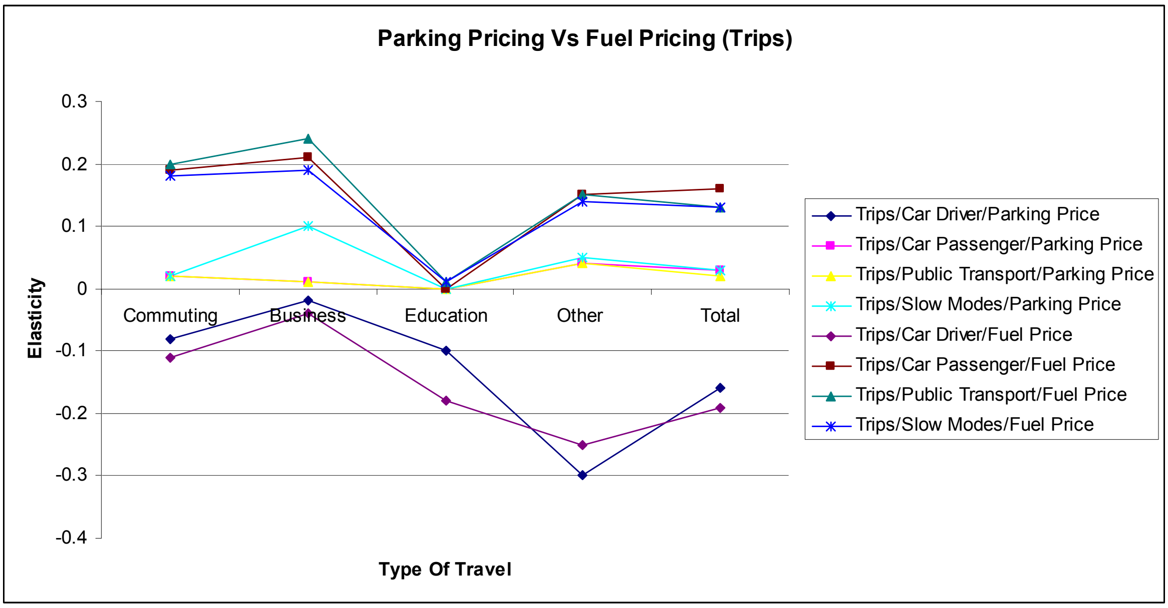
Source: TRACE (1999) in Litman (2008)

Table 11 provides estimates of **European long-term elasticities** of urban travel in response to fuel costs. A fuel price increase of 10% will affect **car drivers**' **trips** with -1.9% (first column, at the top). Commuting and business trips seem to be less sensitive to changes in fuel prices than travel for other purposes. TRACE (1999) estimated some specific elasticities for **Brussels** assuming a fixed car occupancy rate. The elasticities for car drivers were assumed identical to the elasticities for car drivers and car passengers together. The elasticities from the Brussels model, which is a morning peak model, can be interpreted as *commuting elasticities* (De Jong and Gunn, 2001). These commuting elasticities with respect to car drivers' trips are estimated to be -0.16 on the short run and -0.24 on the longer term, which is in line with the European elasticity (-0,19). Changes in fuel prices appear to have a larger effect on **vehicle-kilometres** than on vehicle trips (first column, at the bottom). Several researchers agree on the fact that the fuel price elasticity of vehicle kilometres should be around -0.15 in the short-term and -0.30 in the long term. The long-term effect is bigger than the short-term effect as destinations further away will become less attractive (De Jong and Gunn, 2001). Here, commuting as well as business travel appear to have a lower than average elasticity. With respect to the *commuting elasticities*, vehicle-kilometres elasticities are estimated to be -0,22 in the short run and 0,31 in the longer term, which is in line with the European elasticity (-0,29).

Trips and kilometres of **car passengers** will be affected too by fuel price changes as cost increases stimulate carpooling (Table 11, second column). **Public transport** is also positively affected by an increase in fuel costs of cars (Table 11, third column). The *commuting elasticities* are estimated to be around + 0.38 in the short term and + 0.37 in the long run. These elasticities are higher than the European elasticities as Brussels is a predominantly urban area where there are a lot of substitution possibilities (De Jong and Gunn, 2001). Even **slow modes** such as walking and cycling are positively influenced by fuel prices and produce elasticities of about +0.13 for trips and kilometres (Table 11, fourth column). According to TRACE (1999), these fuel price elasticities can be also used to predict the impact of **fuel taxes**. If for example fuel prices consist for 60% of fuel taxes, than a fuel tax increase of 10% could be evaluated as a 6% increase in fuel prices. Even **distance-based road pricing** could be simulated using these fuel price elasticities as the amount is dependent on the distance driven, like fuel prices.

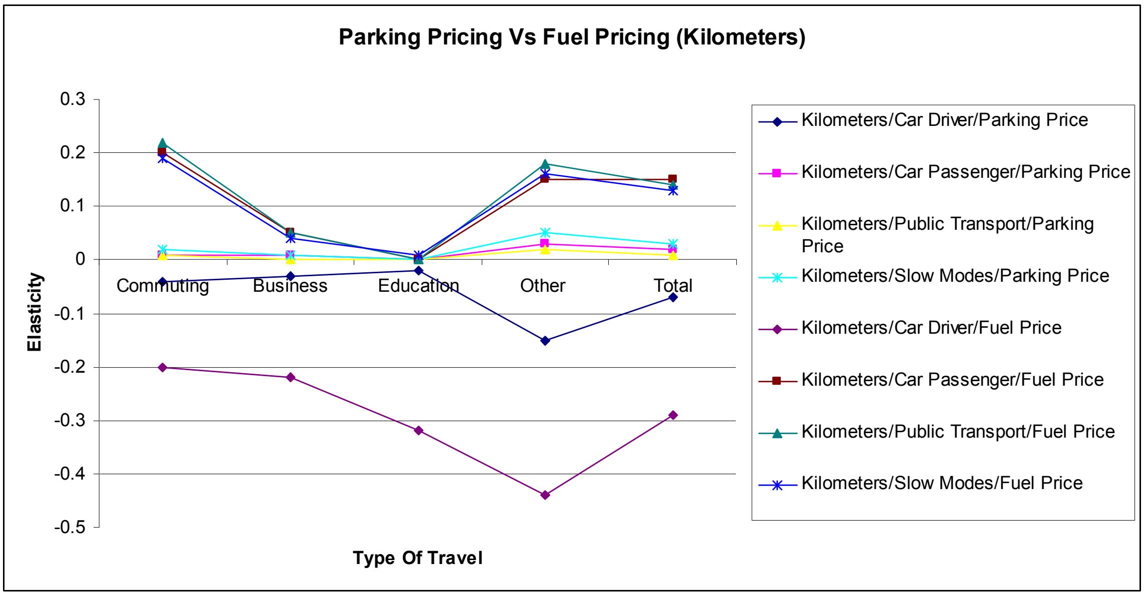
In Figures 16 and 17, the results from Table 9 (Parking elasticities) and Table 11 (Fuel price elasticities) are combined with respect to **trips** and **kilometres**. When comparing the impact of parking prices and fuel prices on trips and kilometers, it appears that fuel prices generally have a larger impact on trips and kilometers than parking prices. Figure 16 also reveals that business trips are quite sensitive to price changes, except for business trips made by car. Educational trips made by carpooling, public transport and slow modes are in contrast almost price insensitive. With respect to kilometers (Figure 17), commuting kilometers appear to be quite sensitive to price changes, whereas educational trips are again highly price insensitive expect for the educational trips made by car.

Figure 16: Parking prices versus fuel pricing with respect to trips



Source: David Zimmer (2008)

Figure 17: Parking prices versus fuel pricing with respect to kilometres



Source: David Zimmer (2008)

B.4.5 Road Pricing and Tolls

Road pricing is defined as a toll paid by people using a particular road or driving in a particular area (VTPI, 2005). A particular case of road pricing is **congestion pricing** where tolls are higher during peak periods and lower during off-peak periods aiming at reducing traffic congestion. In some cases, congestion charging has been producing considerable behavioural effects. The **London congestion charge** for example reduced private automobile traffic by 38% and total vehicle traffic by 18% while affecting the vehicle stock as older cars have been replaced and the amount of diesel cars has increased. The price elasticity was higher than expected, resulting in less generated revenues. Possible explanations for this success is the fact that the city centre was extremely congested, vehicle mode share was only 12% before the introduction of the charges, parking prices were already extremely high and a large variety of efficient transit, subway, rail and taxi services were/are available to and within the centre (Washbrook et al., 2006). Hirschman et al. (1995) used twelve years of monthly time series to derive **bridge and tunnel elasticities** for vehicles in the **New York area**. The median toll elasticity for passenger cars was found to be -0,10, indicating a high inelasticity of vehicle traffic with respect to tolls. A possible explanation for this low elasticity is that it consists of relative low fees as the aim is to collect revenues for transportation system improvement, rather than to reduce vehicle congestion (Washbrook et al., 2006). Another explanation lays in the fact that tolls are common sense in New York and that traffic volume will not be sensitive to such a small, gradual toll increase. A final reservation is that tolls are in fact only a small part of the total vehicle costs. The total price elasticity of vehicle travel will be much larger than the partial elasticity with respect to tolls alone. As the daily total vehicle costs consist for example of tolls, parking fees, fuel costs, vehicle depreciation etc., a multi-faceted price strategy would have a large impact on travel behaviour (Hirschman et al., 1995). Arentze, Hofman and Timmermans (2004) made use of a public survey to investigate the behavioural responses relative to **congestion pricing policies**. For *commuting trips*, travellers will most likely change their route and departure time, whereas a shift to public transport or working at home seems to be a less suitable option. For *non-commuting trips*, shifts to cycling also occur. This confirms the results of Schuitema et al. (2007) saying that changing travel times seems to be perceived as a more feasible option than changing the transportation mode. According to Arentze et al. (2004), the price elasticity of overall vehicle travel is found to be -0.13 to -0.19 (short run) and -0.35 to -0.39 (long run) if a particular congested road is priced, taking into account the shifts to other routes and departure times. **In Singapore**, the electronic kilometre charge resulted into toll elasticities of -0.19 to -0.58, with an unweighted average of -0,34. The toll resulted in an increased traffic before peak hours and a decreased traffic during the peak hours (Luk, 1999). Odeck and Brathan (2008) found out that elasticities vary along -0.45 in the short run and -0.82 in the long run for **Norwegian toll roads**. They also state that policy measures seem to be more accepted if there is a clear communication of how the revenues will be used (see also section B.3.2). Moreover, they discovered that in general, transport demand with respect to tolls is seen as quite inelastic. Out of an overview of studies, toll elasticities were found to vary along -0,5 implying that a 10% increase in tolls results in a 5% reduction of traffic, or less. The variation in the observed elasticities can be explained by several factors such as trip purpose, frequency of trips, toll level, and the existence of toll-free alternatives. In this respect, travel demand seems to be more elastic in case where there are good untolled alternatives. **A reduction in tolls fee** seems to have a larger effect on vehicle travel. In case of the Dulles **Greenway in Washington**, a reduction in toll of 43% has been found to produce an increase in vehicle traffic of 80%, resulting in a price elasticity of -1,9 (UTM, 2000). Glaister and Graham (2003) evaluated the effect of environmental charges and congestion charges on the busiest roads during peak periods in **England**. Environmental charges were defined as additional charges per vehicle kilometre, matching the environmental damage it causes based on vehicle type and location. It has been found that a combination of environmental charges and congestion charges, while keeping fuel taxes at the current rate, would evoke a reduction in overall traffic by about 9%, whilst environmental charges alone would reduce it by 6%. Although environmental charges were found to have relatively small effects compared with congestion charges in highly congested areas, congestion charges only apply to high congested areas whereas environmental charges are universal. Glaister and Graham (2003) also investigated whether it is better to implement **nation-wide charging** or to stick to **location-specific**

charging, bearing in mind the costs of introducing and administrating new charging systems. As new charging schemes are confronted with large capital and operating costs, very large schemes also incorporating wide and less affected areas will produce higher costs than location-specific charging. As a result, Glaister and Graham (2003) advise to research the impact on revenues and benefits of several scenarios with different scales of implementation. Expending the capacity will depend on whether the charges, covering the full cost of capital plus the environmental damage caused to others, exceed the capacity costs.

Overall, the impact of road pricing seems to depend on the **price structure**. Ubbels and Verhoef (2006) report that road pricing in the Netherlands would reduce car trips by 6% to 15%. A **flat** fee tends to affect social trips and evokes a shift towards non-motorized modes, whereas a peak-period fee mainly affects commute trips, and evokes shifts in travel time and mode, and working at home. Also Burris (2003) investigated whether flat-rate tolls or tolls that vary by time or congestion level have a higher impact on travel demand. The flat-rate toll was found to produce an elasticity from -0,03 to -0,35 whereas the variable toll elasticities varied from -0,16 to -1.0. Elasticities of a flat toll are found to be less elastic than the elasticities of a variable toll as this last one offers the drivers the additional flexibility in travel decisions. May and Milne (2000) used an urban traffic model to compare the effects of cordon tolls, distance-based pricing, time-based pricing and congestion pricing. They found out that time-based pricing has the greatest overall benefits, followed by distance-based pricing, congestion pricing and cordon pricing (Table 12).

Table 12: Types of road pricing

Type of road pricing	Fee required to reduce trips by 10%
Cordon pricing (pence per crossing)	45
Distance-based pricing (pence per kilometre)	20
Time-based pricing (pence per minute)	11
Congestion pricing (pence per minute delay)	200

Source: May and Milne (2000)

This result is confirmed by Mayeres and Proost (2004) who estimated the impact of a potential cordon toll around Brussels. They discovered that a cordon toll leads to a positive result, but that it is less efficient than other forms of road pricing. The reason is that a cordon toll limits inbound traffic and that traffic inside the cordon remains and partly increases when inbound traffic falls. Compared to the optimal policy, they found a relative efficiency for the cordoll toll of 52% indicating that the toll needs to be complemented with other supplementary policy measures such as higher parking charges etc.

B.4.6 Kilometre and emissions charges

As seen in previous section, **kilometre charges**, also called **distance-based road pricing**, seem to produce one of the greatest overall benefits. INFRAS (2000) reveals elasticities ranging from -0,1 to -0,8, depending on trip purpose, mode and price level. Schuitema et al. (2007) are in contrast not convinced that the effectiveness depends on the price level, as they found out that even a small kilometre charge can already have a large impact on car use. According to them, small price changes are already effective whereas for other pricing measures stronger price increases are needed to induce the right behavioural changes.

Kilometre charges can take two forms. The first type of kilometre charge is a distance-based charge (in kilometres), based on the average emissions of the vehicle model **(type 1)**. The second type is a charge based on the actual emissions measured during the use of the vehicle **(type 2)**. Table 13 gives an insight in the effectiveness of these two types of kilometre charges.

Table 13: Comparison of two types of emission charges

Region	Fee basis	VMT	Trips	Delay	Fuel	ROG	Revenue
Bay area	Vehicle model	-2,2%	-1,9%	-3,5%	-3,9%	-5,4%	$384
	Vehicle Use	-1,6%	-1,4%	-2,5%	-6,6%	-17,7%	$341
Sacramento	Vehicle Model	-2,6%	-2,3%	-4,5%	-4,0%	-5,7%	$116
	Vehicle Use	-2,3%	-2,1%	-5,0%	-7,4%	-20,2%	$102
San Diego	Vehicle Model	-2,5%	-2,2%	-3,5%	-4,1%	-5,5%	$211
	Vehicle Use	-1,9%	-1,7%	-3,5%	-7,1%	-19,5%	$186
South Coast	Vehicle Model	-2,5%	-2,3%	-5,5%	-3,9%	-5,5%	$1,106
	Vehicle Use	-2,1%	-1,9%	-6,0%	-7,2%	-18,9%	$980

The Fee basis is based on Vehicle-Model or on Vehicle-Use. **VMT** = the change in total Vehicle Mileage. **Trips** = the change in total vehicle trips. **Delay** = the change in congestion delay. **Fuel** = change in fuel consumption. **ROG** = a criteria air pollutant. **Revenue** = annual revenue in millions of 1991 US Dollars.
Source: Harvey and Deaking (1998) in: Litman (2008)

It appears that both have similar effects on the total vehicle mileage, total vehicle trips and congestion delay. However, type 2 has a larger impact on fuel consumption and the resulting air pollutants. It can be concluded that policy measures based upon the produced emissions in **real traffic situations** have a larger impact on fuel consumption and emissions than policy measures based upon emissions, measured by **test cycles**. In that case, people will switch to more fuel efficient vehicles, rather than reducing their total amount of vehicle mileage or vehicle trips. Peters et al. (2008) think however that people will only make the switch to more environmental friendly vehicles if there exist governmental incentives to make these vehicles more affordable. According to them, policy measures need to find the balance between reaching underlying targets such as lowering energy consumption and stimulating the purchase of fuel efficient vehicles. Environmental friendly vehicles may not become too cheap too as there exists a risk in stimulating people to purchase vehicles while they do not necessarily need one.

Ubbels et al. (2001) investigated the effect of a kilometre charge on **car ownership** and found some contradictory results. First results indicated that variabilisation will evoke an increase in car ownership as fixed costs will decrease while variable costs will increase. This effect will probably not lead to a rise in vehicle kilometres as the stimulating effect on car ownership is only expected in groups that are covering relatively few kilometres. Moreover, an increase in car ownership often means the purchase of a second car. As the first car will be used less, these extra cars will probably not lead to many extra kilometres. Other results indicate that variabilisation will lead to a decrease in car ownership as the increase in car ownership will be less than the decrease caused by the higher variable costs.

A final result relates to research performed by Mayeres and Proost (2004) investigating the effect of kilometre charges on **trucks** driving through Belgium. A kilometre charge for trucks can be an interesting way to let transit traffic pay taxes, as they currently pay no fuel taxes in Belgium but cause meanwhile important congestion, accident and environmental costs. The current Eurovignette is only covering the infrastructure costs, no external costs. It has been observed that a kilometre charge on trucks would only have a small effect on congestion levels as latent car demand will take part of the freed road space. In the longer run, an electronic toll differentiated by time and location seems to be a more efficient option as it will charge prices that are more closely related to the marginal social costs. Another option on the long run is letting the transit traffic pay for the use of the infrastructure equal to the marginal operating costs.

B.4.7 Travel Time

A widely used concept with respect to travel time is the **Travel Time Budget (TTB) hypothesis**, referring to the idea that the average daily travel time (70 to 90 minutes) and money budget tend to be relatively constant. People have a certain amount willing to spend on travel and will make adaptations to minimize departures from that amount in either direction (Mokhtarian and Chen, 2004). In this respect, increasing travel speeds and reduced delays tend to increase the travel distance so as to keep travel times approximately constant. Improvements in technology or additions of capacity of the system will result in an increasing traffic volume as people will take advantage of the reduced travel time. Increasing traffic speed with 20% is estimated to increase the traffic volume by 10% in the short term and by 20% in the long run (SACTRA, 1994). As this concept is clashing with the aim of decision makers to minimize travel time, it is important to take this into account. It is however notable that this TTB concept is valid on a aggregate level. At the disaggregate level, there seems to be a high degree of variation between travel time and money expenditures depending on individual and household characteristics, attributes of activities at the destination and characteristics of residential areas. Table 14 summarizes the effects in car travel time on travel demand for other modes and for various types of trips.

Table 14: Long Run Travel elasticities with respect to Car Travel Time

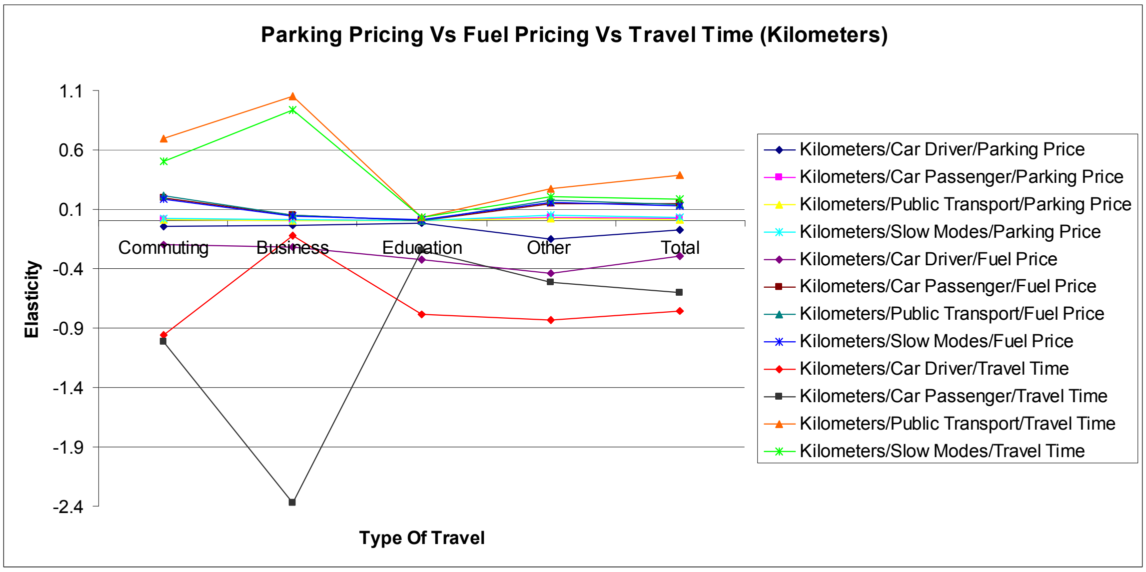
Purpose	Car Driver	Car Passenger	Public Transport	Slow Modes
Commuting	-0,96	-1,02	+0,70	+0,50
Business	-0,12	-2,37	+1,05	+0,94
Education	-0,78	-0,25	+0,03	+0,03
Other	-0,83	-0,52	+0,27	+0,21
Total	*-0,76*	*-0,60*	*+0,39*	*+0,19*

Source: TRACE (1999) in: Litman (2008)

According to De Jong and Gunn (2001), the effect of a percentage change in **car travel time** is greater than the effect of a change in **car cost** by the same percentage. Reviewers of SACTRA (1999) even stipulate that the long-run travel time elasticity of traffic is a factor of two or more times the fuel price elasticity (De Jong and Gunn, 2001). The impact of car travel time on **vehicle kilometres** is also estimated to be greater in the long run than in the short run as in the long-run destination effects are taken into account. A change in car travel time will reduce **vehicle traffic** in the long-run (-0.76) (Table 14, first column). TRACE (1999) estimated *commuter elasticities* for **Brussels** around -0.31 on the short term and about -0.49 on the long term. Changes in travel time will also affect **carpooling** (-0.60) (Table 14, second column). Contrary to the impact of fuel prices on carpooling, this elasticity is negative as an increase in travel time applies to each of the occupants. A car travel time change has a positive impact on **public transportation** (+0.39) (Table 14, third column). As with the direct elasticities, the cross-elasticities for changes in time exceed the cross-elasticities for changes in fuel prices. In the Brussels model, the cross-elasticities for public transportation are estimated to be + 0,60 in the short-run and + 0,50 in the longer term. The total number of trips will decrease in the longer run because of relocation. Travel time increases affect also **slow modes** such as walking and cycling (+0.19) (Table 14, last column). According to TRACE (1999) travel time elasticities can also be used to predict the impact of **congestion on mode choice and distribution/generation**.

In Figure 18, the results from Table 9 (Parking elasticities), Table 11 (Fuel price elasticities) and Table 14 (Travel time elasticities) are combined with respect to kilometres.

Figure 18: Parking pricing versus fuel pricing versus travel time with respect to kilometres



Source: David Zimmer (2008)

Figure 18 reveals that a 10% change in car travel time has a bigger impact on vehicle kilometres than a 10% increase in fuel prices or a 10% increase in parking charges. One exception is the business trips of car drivers, as a 10% increase in fuel prices is found to have a bigger impact than a 10% increase in travel time.

B.4.8 Vehicle price and income

Vehicle ownership and use are affected by price and income. With respect to the **vehicle price**, Goodwin, Dargay and Hanly (2004) report an elasticity of vehicle ownership of -0.4 to -1.0, indicating that a 10% increase in total vehicle costs will reduce vehicle ownership by 4 to 10%. De Borger and Mayeres (2004) researched the impact of money prices and fixed costs on vehicle ownership (Table 15). An increase in costs of a particular car is found to have limited effects on the overall stock, but with larger effects on the composition of the stock.
As fuel costs represent about 25% of the total vehicle costs, an increase in fuel costs of a diesel car for example will decrease diesel car ownership in favour of petrol car ownership. Diesel car ownership is found quite more elastic than petrol car ownership.

The impact of vehicle prices on vehicle ownership also depends on whether it is the **first** vehicle or the **second** or **third vehicle** in the household. The purchase of the first vehicle is primarily dependent on socio-economic factors such as an increase in income, whereas the purchase of a second or third vehicle rather depends on the quality of alternative transportation modes in the community. Here, it is important to make a distinction between **rural** and **urban communities**. Car ownership in urban areas appears to be twice as sensitive to car purchase costs as in rural areas as rural households are more dependent on car use and have little alternative transportation possibilities. In addition, while car ownership is in urban areas mildly sensitive to fuel costs, rural and other households appear to be totally price insensitive to fuel costs. It is important to take these differences into account when introducing policy measures, especially with respect to the distributional aspects. General increases in costs of car transport could pose a considerable economic burden on rural households (Karlaftis and Golias, 2002; Dargay, 2002). Vehicle prices seem to produce considerable effects on **vehicle use** too. Dargay (2004) even stipulates that vehicle prices might have a larger impact on vehicle use than on vehicle ownership. A possible explanation is that as vehicles become less expensive, fixed costs per kilometre will decrease, so there will be a tendency to use the vehicle more. As a result, it will be easier to influence vehicle use than vehicle ownership as the former responds more quickly to prices and is less related with resistance to change.

Table 15: Calibrated elasticity of car ownership probabilities with respect to money car prices and fixed car costs

	Money price				**Fixed costs**	
	Peak petrol car	**Off-peak petrol car**	**Peak diesel car**	**Off-peak diesel car**	**Petrol car**	**Diesel car**
Probability						
No car	0.02	0.03	0.02	0.03	0.07	0.07
Petrol car	-0.12	-0.17	0.15	0.22	-0.37	0.48
Diesel car	0.16	0.23	-0.24	-0.33	0.49	-0.74

Source: De Borger and Mayeres, 2004

Vehicle ownership and fuel consumption are also associated with **income**. The long-run elasticity of vehicle fuel consumption with respect to income is 1,1 to 1,3 and the long-run elasticity of vehicle travel with respect to income is 1,1 to 1,8 (Glaister and Graham, 2000). When comparing the absolute elasticity of fuel consumption with respect to fuel prices to the absolute elasticity of fuel consumption with respect to the income, the last one seems to have the largest impact (see also B.4.3). This means that fuel prices should rise faster than income in order to keep fuel consumption at a constant rate (Glaister and Graham, 2000). The relationship between the growth of **vehicle ownership** and per capita-income is found to be highly non-linear. Vehicle ownership tends to grow relatively slow at the lowest levels of per capita income, then about twice as fast as income at the middle-income levels and finally about fast as income at higher income levels, before reaching a saturation level at the highest levels of income, following a S-shaped curve. Dargay et al. (2007) inventoried historical data on income, vehicle ownership and population during 1960-2002. Historical data for the Belgium case are presented in Table 16.

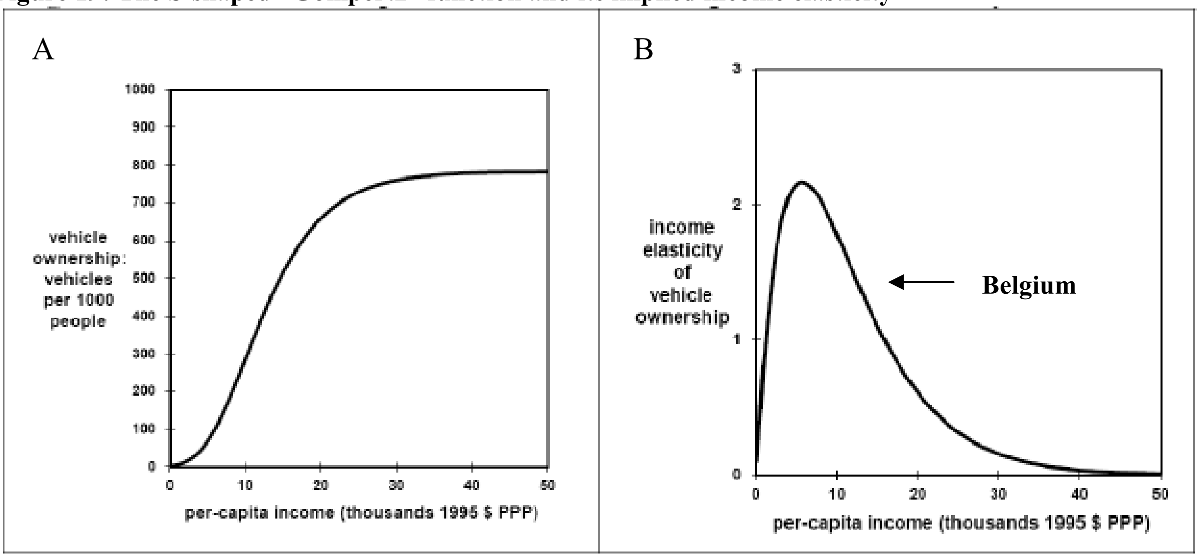
Table 16: Historical data on income, vehicle ownership and population, 1960-2002

Country	Per capita-income (thousands, 1995 $ PPP)			Vehicles per 1000 Population			Total Vehicles (millions)			Ratio of growth rates
	1960	2002	Average annual growth rate	1960	2002	Average annual growth rate	1960	2002	Average annual growth rate	
Belgium	8.2	24.7	2.7%	102	520	4.0%	0.9	5.3	4.3%	1.48

Source: Dargay et al. (2007)

As people getting wealthier vehicle ownership increases, but at a decreasing rate towards a saturation level (Schafer and Victor, 2000). Figure 19A shows the S-shaped curve and the saturation level. The saturation level of Belgium is situated at 647 vehicles per 1000 people. The maximum saturation level is situated at 852 vehicles per 1000 people. This is the saturation level for the USA and for those countries which are less urbanized en less densely populated such as Finland, Norway and South Africa. Saturation levels appear to decline with rising population density and with increasing urbanization (Dargay et al., 2007). Next, the implied long-term income elasticity of vehicle ownership can be derived, based on the ratio of vehicle ownership growth to the per-capita income growth. The long-run income elasticity of vehicle ownership can be found in Figure 19B and it is a country-specific income elasticity.

Figure 19: The S-shaped "Gompertz" function and its implied income elasticity



Source: Dargay et al. (2007)

However, Dargay et al. (2007) found an **asymmetry in vehicle ownership** which might lead to biased estimates of income elasticities. Household vehicle ownership increases as households become wealthier or have more adult workers, but they are less likely to reduce their vehicle ownership at a declining income or with declining adult workers. As a result, an increase or decrease in income will produce different elasticities with respect to vehicle ownership. A falling income will probably encourage households to keep their vehicles, but reducing their vehicle mileage. Vehicle use decreases more when income falls than it increases when income rises. At a higher income, more vehicles are purchased and vehicle use increases. As the number of vehicles does not decline at a falling income to the same extent as it does when income rises, the reduction in vehicle use resulting from a falling income will be larger than the increase in vehicle use resulting from a rise in income.

Dargay et al. (2007) made several projections regarding future trends in income, populations and urbanization to estimate **vehicle ownership to 2030**. The projected growth in vehicle ownership within OECD countries is estimated to be relatively slow, about 0.6% annually, as many of these countries are approaching the saturation level. The annual OECD growth rate for total vehicles is somewhat higher, about 1.4%, due to population growth. The projections of vehicle ownership for Belgium can be found in Table 17.

Table 17: Projections of vehicle ownership to 2030

Country	Per capita-income (thousands, 1995 $ PPP)			Vehicles per 1000 Population			Total Vehicles (millions)			Ratio of growth rates
	2002	2030	Average annual growth rate	2002	2030	Average annual growth rate	2002	2030	Average annual growth rate	
Belgium	24.7	45.3	2.2%	520	636	0.7%	5.3	6.7	0.8%	0.33

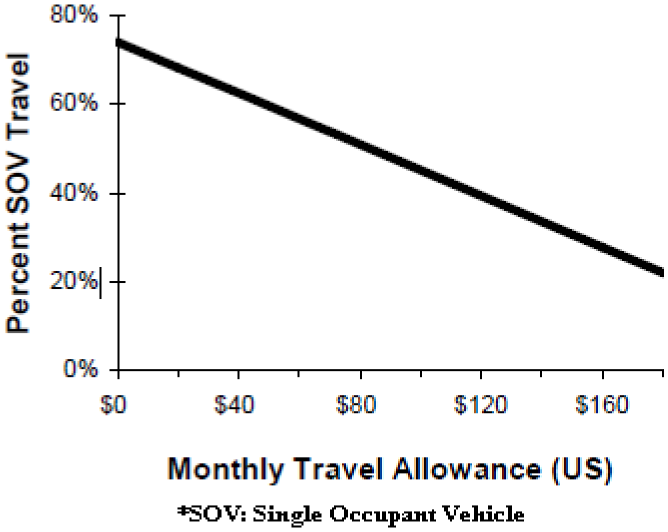
Source: Dargay et al. (2007)

Based on these projections, Dargay et al. (2007) suggest that policy makers should be able to slow down the expansion of the vehicle stock through tax policies, promotion of public transport, and appropriate urban planning.

B.4.9 Commute trips and Financial initiatives

Washbrook et al. (2006) estimated the **commuter response** of 548 commuters to various policy oriented combinations of **charges and incentives**. It has been found that increases in drive alone costs will have a larger impact on travel demand than increases in drive alone travel time or improvements in times and costs of alternative transportation modes. Road pricing was found more effective in reducing vehicle demand than parking charges. Fiscal disincentives should however be accompanied with an improved supply of alternative travel modes in order to effectively reduce vehicle demand. Financial disincentives could also have a larger impact on lower income households. Lower income respondents are more likely to be a member of one-vehicle households and have less opportunity to carpool. Also, they may be unable to avoid paying charges if the improved supply of alternative transportation modes is not available. Overall, commute travel tend to decline as companies provide financial incentives (Figure 20).

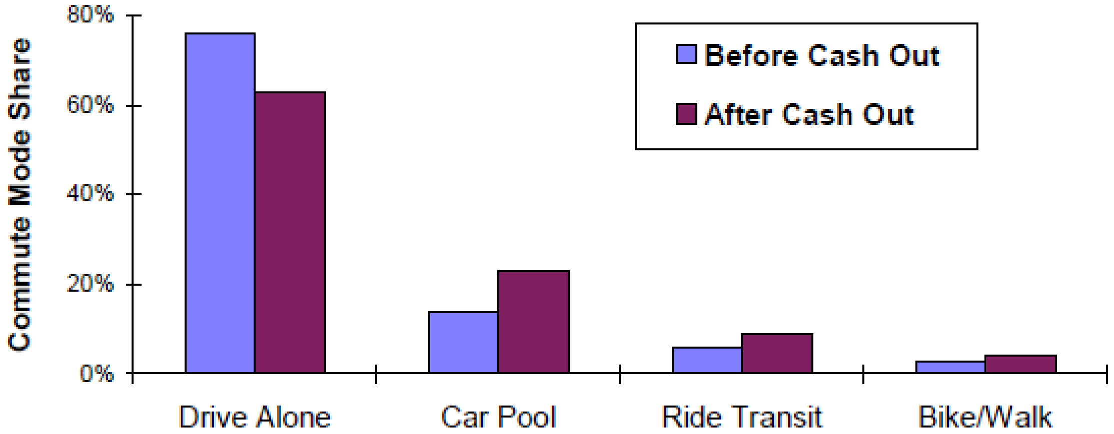
Figure 20: Effect of financial incentives on Single Occupant Vehicle (SOV) commuting



Source: Rutherford (1995) in Litman (2008)

The effects of financial incentives even increase over time. Schoup (1997) demonstrates that solo commuting declined with 17% after cashing out parking fees (Figure 21). There was still an effect three years after the introduction of cashing out as the commuters found more possibilities to reduce their driving.

Figure 21: Impact of cashing out on commuting mode



Source: Schoup (1997)

B.4.10 Mode shifts

As already mentioned, vehicle use tends to decrease at increases in vehicle operational costs such as fuel costs, parking fees etc. Some of this travel will disappear as people will make fewer and shorter trips or by working at home. Another part of the reduced vehicle use will be replaced by an alternative transportation mode. Which changes occur depends on the type of trip, route, quality of the available substitutes and type of traveller. In general, people will switch to cycling or walking for shorter distances, whereas public transportation (urban areas) and carpooling (rural areas) will be used for longer distances. Policy measures aiming at reducing vehicle use generally cause 20 to 60% of vehicle trips to shift to public transportation. Other trips will be replaced by cycling, carpooling or will disappear. Improving the quality of public transportation will attract 10 to 50% out of the vehicle trips. Research performed by Volusia County Public Transit (in: Litman, 2008) discovered that 25 to 58% of the users of public transportation would switch to vehicle trips in case of unavailability of public transit (Table 18) . This substitution is found to be higher in more vehicle dependent areas, and lower in multi-modal areas where consumers have a larger variability of other transportation modes available.

Table 18: Alternatives to transit travel

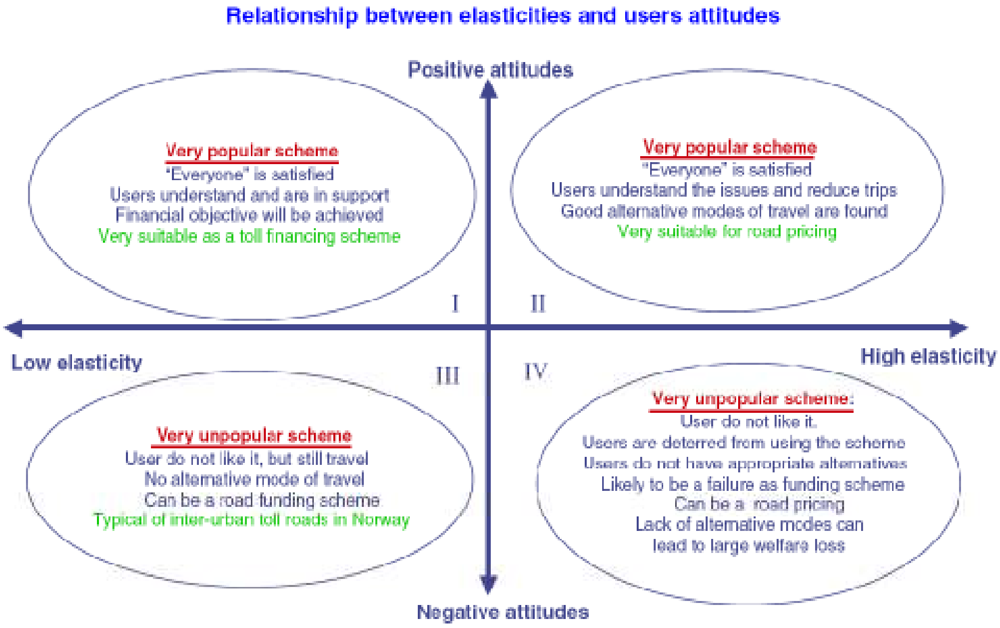
How would you make this trip if not by bus?	**Frequency**
Ride with someone*	626 (33%)
Walk	369 (19%)
Would not make the trip	262 (14%)
Taxi*	245 (13%)
Drive*	147 (8%)
Bicycle	161 (8%)
Paratransit service*	57 (3%)
Other	56 (3%)
Total	*1.923 (100%)*

Source: Volusia County Public Transit in: Litman (2008), *Increases vehicle trips

B.5 Evaluation of policy measures

When it comes to the evaluation of policy measures, on should take not only the **travelers'attitudes** (see section B.3) into account, but also the **elasticities** (see section B.4). Travelers'attitudes only do not necessarily result into actions because of several reasons (principles of users, availability of alternatives, accessibility, ...). So one should link it to the elasticities in order to get an insight in the effectiveness of policy proposals. For this purpose, the taxonomy, developed by Odeck and Brathan (2008) can be used. They set up a preliminary taxonomy for the link between demand elasticities and travelers'attitudes with respect to tolls (Figure 22).

Figure 22: Concept for the evaluation of policy measures



Source: Odeck and Brathan (2008)

Figure 22 shows four possible combinations with respect to elasticities and users attitudes. In **Quadrant IV**, users have a negative attitude towards the policy measure and the elasticity is high. This is an unfavourable situation for the implementation of a policy measure. First of all because there is a negative attitude towards the policy measure. As seen in previous sections, the acceptability of the policy measure by the people is a crucial factor for an effective policy. Secondly because of the high elasticities. High elasticities may refer here to the fact that users are deterred from using the scheme or that they have no other possibilities of alternative transportation modes or changing destinations leading to large welfare losses. **Quadrant III** refers to a negative attitude and a low elasticity. A possible reason for the low elasticity is the non-understanding or non-acceptance of the policy. Another explanation may be the that the change in price is relatively low resulting in a situation where they still continue to travel. These elasticities can however increase on the longer term as people will adjust their travel patterns. Policy measures situated in Quadrants III and IV seems thus not advisable as they suffer from a lack of information and a low understanding. An increasing understanding of the policy measure has been reached in Quadrants II and I. In **Quadrant II,** travellers show positive attitudes. The elasticity is high indicating that they will probably not travel by road as they have other travel options. This scheme is advisable for introducing **congestion pricing or road pricing**. In **Quadrant I,** travellers have favourable attitudes towards the policy measure and the elasticity is low indicating that they are still travelling by road. This situation can happen when the price change is low and people support the purpose of the policy measure as they are well informed. This situation is advisable for a **road financing scheme**. So policy measures should be preferable situated in Quadrants I and II as the majority of the involved stakeholders will accept it. It has to be noted that this scheme does not take account of distributional impacts. In this respect, elasticities could be low as travellers are rich and will not take their travel costs into account. In this scheme, the average traveller has been represented.

B.6 Conclusion

Policy measures are seen as an effective tool to let drivers base their travel decision upon the marginal external costs instead of the private consumer costs. In theory, the optimal flow in traffic would occur if vehicle users are charged an optimal tax closing the gap between the private and marginal social cost. In practice, there is a strong preference for second-best reasoning due to technological challenges and political objections. To evaluate the effectiveness of a policy measure, one should take the travellers' attitudes, as well as price elasticities into account. In a first part, several factors affecting price sensitivity have been identified such as type of price change, characteristics of the pricing policy, type of trip and traveller, quality and price of alternative routes and destinations, scale and scope of pricing and time period. In a second part, a literature review of price elasticities has been performed. The price elasticity of travel demand measures the reactivity of a change in price on travel demand, both measured in percentage changes. An overview of disaggregated elasticities has been performed with respect to several price components such as vehicle operational costs, parking costs, fuel costs, tolls fees, emissions charges, travel time costs, vehicle price and income, commute trips and financial incentives and their resulting changes in travel demand ranging from changes in travel modes, destination, travel routes, departure times and trip patterns to changes of residence and employment location. Out of this review, the following conclusions can be drawn. Belgian consumers are on average more sensitive for their vehicle expenses than for their public transport expenses. Household **income** has the largest impact on fuel consumption, followed by fuel prices. This means that fuel prices should rise faster than income to keep fuel consumption at a constant rate. Increasing **fuel prices** are found to have a larger effect on fuel consumption than on vehicle traffic as the rapid behavioural responses such as changes in driving speed or style, or modifying to the least energy-inefficient trips will affect fuel consumption more than traffic. As a result, **fuel taxes** will be more effective in reducing fuel consumption than in reducing road congestion. Moreover, they are found to affect vehicle trips and kilometres more than **parking charges.** Fuel taxes alone are however not politically attractive. That is why Small and Van Dender (2007) advise to introduce **fuel-efficiency regulations** too as it would promote technological improvements whilst evoking vehicle-mix shifts towards more fuel-efficient vehicles. Such a system will on the other hand hardly affect safety, congestion and noise. From these perspectives, it may be desirable to make the tax system more variable. **Time-based pricing** is found to produce the greatest overall benefits, followed by distance-based (kilometre) charging, congestion pricing and cordon pricing**. Kilometre charging** based on real traffic emissions will have a larger impact on fuel consumption and emissions compared to kilometre charges based on measured emissions from drive cycles. Kilometre charges are seen as a very effective tool as it makes it possible to differentiate according to energy-use, emissions, noise, road safety, driving style and congestion. As a result, people will switch to more fuel-efficient vehicles, rather than reducing their total amount of vehicle mileage or vehicle trips. These findings are in line with the results obtained from the face-to-face and web-based surveys. The surveys also revealed that an **extra pollution tax**, based on the environmental performance of cars, would be effective in discouraging the use of fuel-inefficient cars. Out of the price elasticity review, it appears that policy measures affecting purchase prices and fixed costs would indeed evoke a shift in the composition of the stock towards the most fuel-efficient car, but with a limited affect on the overall stock. Finally, a scheme for the evaluation of policy measures has been presented, in which the travelers'attitudes are linked to the price elasticities in order to get an insight in the effectiveness of policy proposals. **Congestion pricing** or **road pricing** will be effective if travellers have a favourable attitude towards the policy measure and if the elasticity is high indicating that they will probably not travel by road as they have other travel options. **Road financing schemes** will be effective when travellers have favourable attitudes and when the elasticity is low indicating that people support the purpose of the policy measure and that they are still travelling by road.

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