



Transport Elasticities: Impacts on Travel Behaviour

Understanding Transport Demand to Support Sustainable Travel Behaviour
Sustainable Urban Transport Technical Document # 11



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Victoria Transport Policy Institute (VTPI)

The Victoria Transport Policy Institute (VTPI), founded by **Todd Litman**, is an independent Canadian research organisation dedicated to developing innovative solutions to transport problems.

VTPI provides a variety of resources to help improve transportation planning and policy analysis. These resources are available free at VTPI's website www.vtppi.org

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Executive summary

Life is full of trade-offs. People must choose how to spend their scarce resources. The decisions they make reflect their options, needs and preferences. People can meet their transport needs by making use of one or various travel options, such as bicycle, public transport or car travel. There are various factors influencing the feasibility, suitability and desirability of these options. Depending on these factors, people will choose their preferred option and behave following a particular travel pattern.

From a sustainability perspective, it is important to understand well these factors, if effective transport policies are to be implemented. One necessary and key approach to promote sustainable transport is to introduce the right measures on the demand side, favouring more environmentally-friendly options and thus encouraging positive travel behavioural changes.

The aim of this paper is to help understand travel demand and provide practical orientation on how travel behaviour can be improved. For this purpose, the paper examines the factors affecting travel demands, introduces the concept of elasticity and provides an overview of the key transport elasticities.

In conclusion, more sustainable travel patterns can be achieved through the implementation of adequate and effective policy measures that influence the responsiveness of travel demand to various transport options. This enables desirable modal shifts, helping improve the efficiency of transport systems and providing far-reaching benefits to the society.

1 Introduction

People make decisions on how to spend scarce money and time on transport, reflecting in this way not only their mobility needs but also their options and preferences. Economists call these *demands*, which refers to the amount and type of goods people and businesses will consume under specific conditions. People choose how much to travel, when and how based on what they can afford and what they consider it is their best option. Economics studies these issues and analyses how consumers behave.

Many factors affect peoples' consumption patterns, including monetary costs (reflected in prices) and various non-monetary costs such as time, discomfort, risk, and status impacts. Examples of non-monetary costs are the time spent travelling to and from the bus stop or station (and its quality, e.g. exposure to weather and unsafe traffic or personal security conditions), travel time on the bus (and its quality, e.g. sitting vs. standing in

crowded conditions), and other important user-perceived attributes (e.g. if riding the bus is seen as causing a loss of status or is accepted behaviour among the user's peers).

Price changes can affect travel decisions in various ways. When transport prices decline, mobility (the amount that people travel) tends to increase, and if prices increase, mobility tends to decline. Transport price changes can affect trip frequency, route, mode, destination, scheduling, vehicle type, parking location and type of service selected. Such decisions are considered *marginal*: they are between similar alternatives and so may be influenced by small price changes. Although individually such decisions may seem variable, in aggregate they tend to follow a predictable pattern: price reductions usually increase consumption, and when prices increase consumption declines. This is called the *law of demand*.



Figures 1: Conductor on a bus (left) and Bus Rapid Transit (BRT) ticket office (right). In addition to monetary costs such as bus fares, peoples' consumption patterns are affected by non-monetary costs such as travel time on the bus, its safety, quality and comfort as well as status impacts and other important user-perceived attributes.

Source: Bangkok (Thailand), GIZ Photo Album 2010 (left); Bogotá (Colombia) (2007), GIZ Photo Album 2010 (right)

Methods described later in this report can be used to quantify how specific price changes affect transport decisions using *elasticities*, which measure the change in consumption that results from changes in factors such as prices, incomes or service quality. This information has many practical uses. Planners can use it to predict how demographic and economic trends will affect future travel demands. Policy-makers and businesses can predict how fuel tax, parking fee, road toll and public transport fare changes would affect travel activities and revenues. It can be used to evaluate various *Transportation Demand Management* (TDM, also called *Mobility Management*) strategies intended to change travel activity in order to achieve various planning objectives (see Box 1).

Although key economic concepts are concisely explained in blue boxes, this report is not intended to be an economics book nor does it provide an exhaustive survey and analysis of transport elasticities. Those interested in more detailed economic explanations, including rigorous mathematical formulations, should refer to our Chapter “Selected References and Further Reading” and access an economics textbook^[1].

This report is however an easy and accessible introduction to the issues presented in this section. It describes

^[1] Since the issues discussed in this report are the focus on what is known as Microeconomics, the interested reader should refer to, for example, Pindyck and Rubinfeld (2012) or Varian (2010) for the basics. More advance microeconomic texts are, for example, Varian (1992) or Mas-Colell *et al.*, (1995).

Box 1 Key references

This paper is intended to be complemented with the following GIZ-SUTP modules:

- “Transportation Demand Management (TDM)”: www.sutp.org/index.php/en-dn-td
- “Mobility Management (MM)”: www.sutp.org/index.php/en-dn-th2
- Case Study “Mobility Management & Commuting: Inputs and Examples of Best Practice in German Firms”: www.sutp.org/index.php/en-dn-cs

These modules can be downloaded free of charge from: www.sutp.org.

concepts related to transport demands, investigates how prices and service quality affect transport activity, discusses how these impacts can be measured, and summarises various transport elasticity studies. Furthermore, it indicates how this information can be used for policy and planning analysis.

Box 2 Transferability

A key factor in this report is the degree to which the transport demand factors and elasticity values it describes are transferable to other times and places. Many of the studies summarised in this report are many years or decades old, and most were performed in higher-income countries. However, it is commonly believed that, with care, these can be applied to current conditions or developing country conditions.

Certainly, when applying elasticity values in a particular situation, it is important to take into account factors such as differences in employment rates, incomes, transport options and land use patterns. However, the basic relationships that affect travel demands tend to be durable and therefore transferable. People have limited money and time to spend on transport and so will respond similarly to changes in their money and time costs. Poor people will tend to be more sensitive to price changes and rich people will tend to be more sensitive to changes in travel time or travel quality.

In some situations, fuel price or road toll increases may cause little vehicle travel reductions, suggesting that the elasticities in this report do not apply. However, this probably reflects factors such as high motorists’ incomes and poor quality alternatives. If these factors are considered by measuring price increases relative to incomes and considering examples where alternatives to driving are inferior, elasticity values from other times and places will probably be transferable.

The values described in this report provide a reasonable starting point for travel demand analysis and modelling. As transport planners, economists and modellers gain experience in more countries we will be better able to predict travel activities in specific situations.

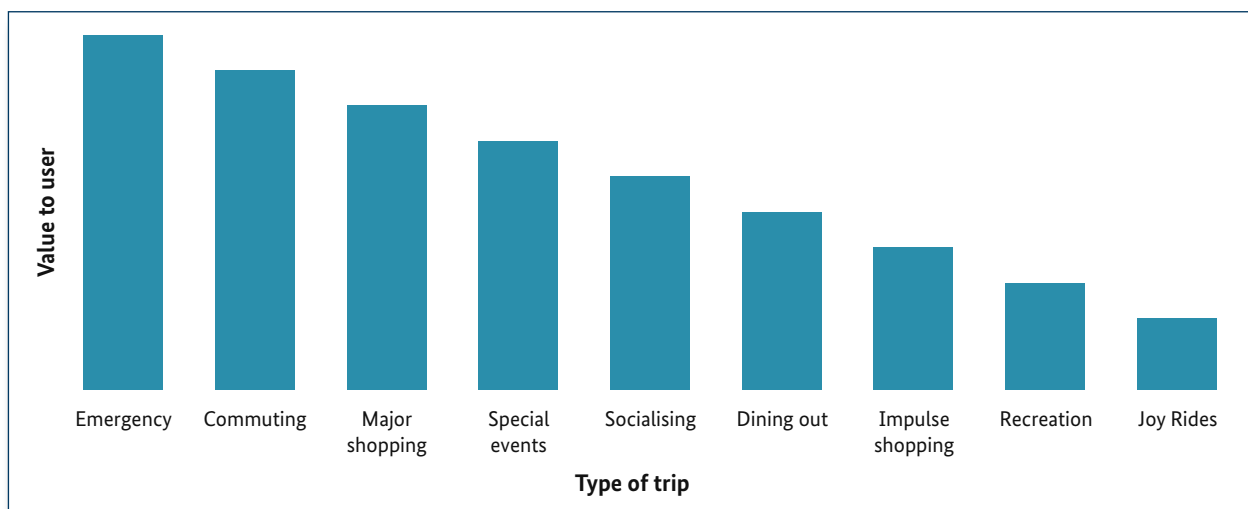
2 Understanding travel demand and travel behaviour

Given an initial endowment and income, people are expected to make rational economic decisions after evaluating the costs of the different options they have to meet a particular need, *e.g.* weekly commuting travel. Their actual travel behaviour will not only reflect this personal economic evaluation but also their preferences.

2.1 Travel demand

Travel demand refers to the amount and type of mobility that people would choose in a particular situation.

This reflects their ability and willingness to pay (see Box 3), and therefore the value they attach to specific travel activity, such as a particular trip or mode. This value can be highly variable: some trips (such as commuting and visits to healthcare services) are important so people take them even if their price is high, but others (such as impulse shopping and some recreational trips) are lower value and so people will only take them if they are cheap. This is illustrated in Graph 1. As a result, the number of trips people take tends to increase as travel costs decline, making lower-value trips seem cost effective.



Graph 1: Travel Ranked by User Value

Trips range in value. Some trips are highly valued and so will occur even if prices are high. Other trips are less valuable and will only occur if prices are low.

Source: Litman, 2011

In addition to understanding user value for different types of trips, it is crucial to understand the relationship between prices and quantity of travel, which can be represented by travel demand curves (see Box 4). For example, some people might choose a home that requires very long commutes if the costs associated with that commuting are low. Similarly, if vehicle travel prices are low, people will use car for trips that could easily be made by other modes, and will drive alone for urban trips that could be made efficiently by public transport.

Box 3 Affordability and preferences

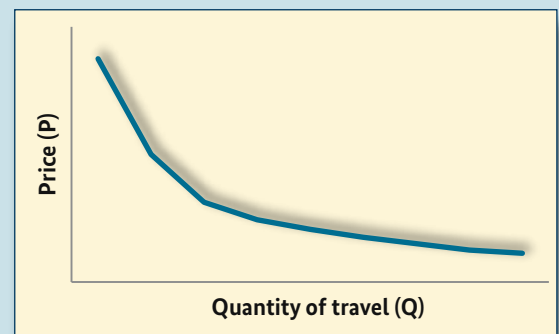
People consume the quantity of travel they can afford. People's travel decisions are therefore limited by their ability to pay for various trips.

In addition to what they can afford, people consume travel in accordance with their preferences, which can be expressed in their willingness to pay for different options. For example, a person may be willing to pay a higher price for making a trip on a train than on a bus, thus reflecting not only her ability to pay but also her preferences.

Box 4 Travel demand curve

The travel demand curve is the graphical representation of the relationship between quantities and prices. This travel demand curve indicates how changes in price affect the quantity of travel consumed. The higher the price, the less quantity of travel consumed. If the curve moves to the left or right, we said that the demand curve "shifts" (e.g. the quantity of travel increases if the curve shifts to the right).

Graph 2: *Travel demand curve*



Source: Litman, 2011

Figure 2: *Parking facility offering the "first hour free". Low value trips such as impulse shopping are only taken if they are cheap.*
Source: Swansea (Wales/UK), Schmid, D. (2011)



Box 5**Travel demands in developing countries**

A few studies have investigated transport demands in developing countries such as:

- Gonzales, *et al.*, (2009);
- Salon and Gulyani (2010);
- Venter, Vokolkova and Michalek (2007)
- Vasconillos, Urban Mobility Observatory (data on 15+ Latin American cities).

2.2 Key factors affecting travel demand

The following factors tend to affect travel demands and hence eventually influence travel behaviour:

Demographics and tastes

Different types of people have different travel demands. Travel, particularly car travel, tends to increase with employment and wealth. Walking, cycling and public transport demand tend to be higher for people who are younger, older, poor, have impairments, are immigrants, enjoy exercise, and live in urban areas. Moreover, people's tastes, which change over time, can also influence travel demand.

Geography and land use patterns

Land use factors such as density, mix, roadway connectivity, building design and parking supply can affect transport demand (CARB 2010/2011; Litman 2008). Per capita vehicle ownership and travel tend to be higher in rural and automobile-dependent suburban areas, while walking, cycling and public transport travel tend to be higher in urban areas, particularly those developed prior to 1950, or more recently with transit-oriented (TOD) or smart growth development policies.

Economic activity

Commercial (business) activity has special travel demands, including heavy freight transport, local

deliveries, service vehicles (plumbers vans and utility trucks), business travel, and tourist travel. This type of travel tends to have high value and may require special vehicles, including rail, large trucks and buses, delivery fleets, and air travel.

Information about options

Due to inadequate information, many travellers are unaware of the options available to them and the attributes of those options, or they may be making decisions based on out-of-date or incorrect information. Without changing the available options or its attributes, marketing can change travel behaviour and implicitly the elasticity of demand (Werner Brog, Socialdata).



Figure 3: Information about travel options as well as on the availability of these options is highly important.

Source: Beijing (China), Breithaupt, M. (2009)

Quality of transport options

The quality of transport options affects travel activity. In many cases, improving walking and cycling conditions, and public transport service quality, tends to increase use of these modes and reduce automobile travel. Conversely, in some situations, improving alternative modes may leverage additional motor vehicle travel reductions by helping to create communities where residents own fewer automobiles and drive less overall (ICF 2010).

Demand management strategies

Transportation Demand Management (TDM) refers to various policies and programmes specifically intended to affect travel activity, in most cases, to reduce urban-peak motor vehicle traffic. These strategies include improvements to alternative modes (walking, cycling, public transport, car-sharing, etc.), pricing reforms and other incentives to reduce vehicle travel, and smart growth land use policies. See Box 1.

Price (monetary cost)

The price of transport, which represents the monetary cost for the consumer, is one of the most important factors affecting travel demand. As described in more detail in Chapter 3, vehicle, road, parking, fuel, insurance and public transport prices, among others, tend to affect travel activity in a particular way. Increased prices for a

particular type of travel tends to reduce its consumption and sometimes causes shifts to alternatives.

Income

People’s ability to afford given amounts of travel is also determined by income. If an individual benefits from an increase in her salary, she can afford making use of more expensive modes of transport or travelling more often. Thus the increase in income leads to an increase in the quantity of travel she demands.

Table 1 summarises factors that can affect travel demand. Information on these relationships can be used to model travel demands and predict how various transport system changes will affect travel activity in a particular situation, for example, how a change in fuel price will affect vehicle travel, or how changes in public transport fares or service quality will affect public transport patronage. For this purpose, elasticity values are used.

Table 1: Factors affecting travel demand

Demographics	Commercial activity	Transport options	Land use	Demand management	Prices
<ul style="list-style-type: none"> ■ Number of people (residents, employees and visitors). ■ Employment rate ■ Wealth/incomes ■ Age/lifecycle ■ Lifestyles ■ Preferences 	<ul style="list-style-type: none"> ■ Number of jobs ■ Business activity ■ Freight transport ■ Tourist activity 	<ul style="list-style-type: none"> ■ Walking ■ Cycling ■ Public transport ■ Car-sharing ■ Automobile ■ Taxi services ■ Telework ■ Delivery services 	<ul style="list-style-type: none"> ■ Density ■ Mix ■ Walkability ■ Connectivity ■ Public transport service proximity ■ Roadway design 	<ul style="list-style-type: none"> ■ Road use prioritisation ■ Pricing reforms ■ Parking management ■ User information ■ Promotion campaigns 	<ul style="list-style-type: none"> ■ Fuel prices and taxes ■ Vehicle taxes & fees ■ Road tolls ■ Parking fees ■ Vehicle insurance ■ Public transport fares

This table indicates various factors that affect transport demand, which should be considered in transport planning and modelling, and can be used to manage demand.

Source: Litman, 2011

2.3 Transport prices

As described earlier, the price of transport is one of the key factors determining the quantity of travel people consume. There are various issues related to prices that need to be considered, as they affect how much a change in prices impacts travel activity.

- Commute trips tend to be less elastic than shopping or recreational trips.
- Weekday trips may have very different elasticities than weekend trips.
- Urban peak-period trips tend to be price inelastic because congestion discourages lower-value trips, leaving only higher-value car trips.
- Off-peak trips tend to be more price sensitive.

Type of price change

Different types of price charges can have different impacts on travel behaviour, as summarised in Table 2. For example, fixed vehicle purchase and registration fees can affect the number and type of vehicles purchased. These impacts depend on the specific type of pricing – for example, increased residential parking fees are most likely to affect vehicle ownership, and a time-variable parking fee can affect when trips occur.

Purpose and type of trip and time of day

Elasticities tend to vary by purpose and type of trip:

- Commercial (business) travel tends to be less price sensitive than personal travel.

Quality and price of alternatives

Price sensitivity tends to increase with the quality and affordability of alternative routes, modes and destinations. In general, the wider the range of options (alternatives) transport users have available, the higher the elasticity of demand.

Time period

Transport elasticities tend to increase over time as consumers have more opportunities to take prices into effect when making long-term decisions. For example, if consumers anticipate low automobile use prices they are more likely to choose an automobile dependent

Table 2: Impacts of different types of pricing

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

Different price changes have different impacts on travel behaviour.

Source: Litman, 2011

suburban home, but if they anticipate significant increases in driving costs they might place a greater premium on having alternatives, such as access to public transport and shops within convenient walking distance.

For this reason, the full effects of a price change often take many years. Short-term elasticities (usually defined as less than two years) are typically one-third of long-term elasticities (more than 10 years) (Dargay and Gately 1997). It is argued (Dargay and Goodwin (1995)) that the use of static elasticities ignores travellers' ability to respond to changes over time. Thus static elasticities skew investments toward increasing highway capacity, and undervalues public transport, TDM, and "No Build" options.

Large and cumulative price changes

In general, elasticities are calculated based on small 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 differently.

Price structure

Transport prices can be structured in various ways. Consumers tend to prefer simple price structures that minimise their effort, but are often willing to respond to special incentives. Bonsall *et al.*, (2006) found the following:

- The method and timing of payments influences purchasing behaviour.
- A significant proportion of consumers "disengage" if they perceive cost structures to be too complex. This may lead them to avoid that expenditure.
- Attitudes to motoring costs appear to differ from other expenses. Drivers rarely consider the costs of individual journeys – motoring expenses are widely perceived as unavoidable periodic events.
- There appear to exist various consumer types who share distinct attitudes, preferences and behaviours, and these 'types' reflect age and gender more than income.

One study found that motorists respond 2.25 times as much to a new parking fee (they pay more if they use a parking space) than a parking *cash out* incentive (they receive a rebate for reducing their use of parking spaces) of the same amount (Shoup 1997).

Box 6

How, when, and how often you pay affects elasticity

When users pay public transportation fares every day through the farebox they are more sensitive to the price than if they are using a pre-paid public transport fare instrument, such as a monthly or weekly fare card or debit card. Similarly motorists are more keenly aware of tolls when paid at a toll booth in cash than when paid using automated electronic toll systems or pre-paid toll permits (Replogle, 2008). Motor vehicle insurance may be paid at a fixed rate for a period of half a year, but studies have shown that when the same fee is turned into a distance-based charge, it is likely to result in an 8% decrease in distance driven (Brookings Institution, 2008).

Level of income and share spent on travel

Elasticities tend to vary by type of traveller and her ability to pay. Thus the level of income affects price sensitivity. In general, higher income travellers tend to be less price sensitive than lower-income travellers.

Prices tend to have greater impacts as they increase relative to consumers' income, so elasticities tend to increase with the total size of the costs involved and decline with incomes. Elasticities tend to be higher as prices increase relative to consumers' total household incomes.



Figure 4: Petrol station. It is estimated that the elasticity of fuel consumption with respect to income is 0.45 in the short-run and 1.2 in the long-run.

Source: Liberia, Fremer, P. (2010)

Box 7 Fuel prices reform

In 2010, Bolivia attempted to implement a fuel price reform, without success. A case study illustrates this failure to increase the prices for fossil fuels. The study can be freely downloaded from the GIZ International Fuel Prices website: www.giz.de/Themen/en/29957.htm

■ Fuel Price Reform in Bolivia: www.giz.de/Themen/en/dokumente/giz2011-fuel-price-reform-bolivia-december-2010.pdf

3 Measuring sensitivity: transport elasticities

3.1 The “responsiveness” of travel demand

The effects that transport system changes have on mobility is generally referred to as its “responsiveness” or “sensitivity” to a specific variable or factor, which are measured using elasticities. They are unitless ratios and can be used to evaluate many types of impacts.

Some of common ratios (elasticities) in transport are:

- The elasticity of automobile mode split with respect to the ratio of automobile and public transport travel time for a particular type of trip.

- The elasticity of automobile mode split with respect to the ratio of automobile operating costs and public transport fares.
- The elasticity of household vehicle ownership and per capita vehicle ownership with respect to the quality of public transport service in a community.

Some types of elasticities are specific to transport. A *public transport service elasticity* indicates the percentage change in public transport patronage resulting from a percentage change in public transport service-kilometres. A *travel speed elasticity* indicates the percentage

Box 8: Short versus long-run elasticities and cross-elasticities

Demand is usually more elastic in the long-run than in the short-run. This makes a lot of sense because over time consumers can more easily adjust their consumption patterns. For example, over the long-run transport users can react to fuel price increases by shifting to other transport modes, buying more fuel efficient vehicles, and choosing more accessible home locations.

For this reason, short-run elasticities tend to have lower values than long-run elasticities. For example, Glaister and Graham (2002) estimated that the elasticity of fuel consumption with respect to income is 0.45 in the short-run and 1.2 in the long-run.

Cross-elasticities refer to the percentage change in the consumption

of a good resulting from a price change in another, related good. For example, car travel is

complementary to vehicle parking, and a substitute for public transport travel.



Figures 5: Parking meter. As a result of cross-elasticities, an increase in the price of driving tends to reduce demand for parking and increase demand for public transport travel.

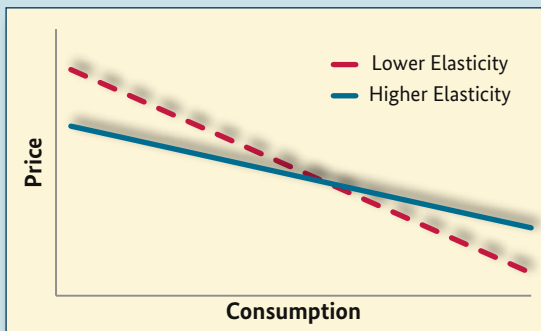
Source: Penang (Malaysia) (2010), GIZ Photo Album 2010 (left); Las Palmas (Spain), Neumann, K. (2007) (right)

change in travel (vehicle-kilometre or public transport passenger-kilometre) caused by a percentage change in the travel speeds for those trips. Although the focus of this paper is on demand, there are also other supply-side

Box 9 Understanding responsiveness

Price elasticities (also called price sensitivity or responsiveness) indicate the steepness of the demand curve. A high sensitivity (a gradual curve) indicates that relatively small price changes cause relatively large changes in travel activity. A low sensitivity (a steep curve) indicates that price changes have relatively little impact on travel. The steepness of the demand curve indicates the ease with which users can change their consumption patterns. For example, if public transport travel is convenient and comfortable, a small increase in parking fees will cause a relatively large number of travellers to shift from driving to public transport.

Graph 3: Price sensitivities



A steeper demand curve (dashed red line) indicates that consumption is less price sensitive (low elasticity), implying that consumers find it difficult to change their consumption patterns. A more gradual demand curve (solid blue line) indicates that consumption is more price sensitive (higher elasticity), implying that consumers find it easy to change their consumption patterns.

Source: Litman, 2011

elasticities^[2]. Other ways of categorising elasticities is by e.g. timeframe (short and long-run elasticities) and the good being considered (e.g. own and cross-elasticities) (see Box 8).

Two of the most common types of elasticities are:

- **Price elasticity of demand (PED):** defined as the percentage change in consumption of a good caused by a percentage change in its price. This value is generally negative since higher prices reduce consumption.
- **Income elasticity of demand:** defined as the percentage change in consumption caused by a percentage change in consumers' income. This value is generally positive since higher income increases consumption.

3.2 Interpretation of elasticities

Elasticities can be classified according to the direction of change:

- $E > 0$: Positive; e.g. an increase in income leads to an increase in demand.
- $E < 0$: Negative; e.g. an increase in price leads to a decrease in demand.

Elasticity values are usually expressed in absolute terms^[3] and are classified by their magnitude as:

- $E = |<1|$: *Inelastic*, meaning that prices cause less than proportional consumption changes. The demand is said to be inelastic.
- $E = |1|$: *Unit elasticity*, meaning that price changes cause proportional consumption changes.
- $E = |>1|$: *Elastic*, meaning that price changes cause more than proportional consumption changes. The demand is said to be elastic.

For example, both 0.5 and -0.5 values are considered *inelastic* because their absolute values are less than 1.0, while both 1.5 and -1.5 values are considered *elastic*, because their absolute values are greater than 1.0.

Johansson and Schipper (1997) estimated that the elasticity of demand for car fuel with respect to (abbreviated WRT) fuel price is -0.7 in the long-run. This means that

^[2] For example, the price elasticity of supply indicates the percentage increase in transport services (such as public transport vehicle-kilometres or the number of taxis) caused by an increase in prices.

^[3] This means in practical terms that the sign of the elasticity value is ignored. In other words, an elasticity value of -1 becomes $|1|$.

an increase of 10% in fuel prices will reduce the demand for fuel by 7% in the long-run. Therefore it can be considered that the demand for car fuel is inelastic (has a low sensitivity) to fuel prices, even in the long-run!



Figure 6: Fuel prices at a petrol station. The elasticity of demand for car fuel with respect to fuel price is inelastic. Thus increasing fuel prices is expected to have little impact on the demand for car travel unless complementary measures are also implemented. Source: Hannover (Germany), Gomez Vilchez, J. (2011)

3.3 How to calculate elasticities

It is important to clearly define the variables being measured, for example, “the elasticity of public transport patronage WRT fares” or “the elasticity of vehicle-kilometres WRT fuel price”, while other variables are held constant.

Several methods are used to compute elasticities, some less simple and more accurate than others (e.g. Pratt 2003; TRL 2004). A simplistic method, called a *shrinkage ratio* (or *shrinkage factor*), is defined as the percentage change in consumption caused by a percentage change in price relative to the original consumption and price. For example, applying a -0.4 price elasticity to a 20%

price increase predicts an 8% reduction on consumption ($0.4 \times 0.2 = 0.08$). Although easy to use, this method is only accurate for relatively small price changes. Box 10 shows the basic formula^[4].

^[4] Other references that study more complex methods (e.g. arc elasticities) in a more rigorous way can be found in the last chapter.

Box 10 Elasticity equation

Price Elasticity of Demand: basic general formula

$$E = \frac{\text{percentage change in quantity or demand}}{\text{percentage change in price}}$$

$$\text{or } E = \frac{\% \Delta Q}{\% \Delta P} \quad \text{or } E = - \frac{P}{Q} \times \frac{\Delta Q}{\Delta P}$$

Box 11 Real versus nominal prices

Elasticity analysis should use real (inflation adjusted) prices, as opposed to *nominal* or *current* prices (unadjusted for inflation). For example, if during a time period there is 10% inflation and nominal prices do not change, real prices will have declined by 10%. If during that time period prices increase by 10%, real prices will have stayed constant. If nominal prices increase 20% during that period, real prices will have increased by approximately 10%.



Box 12 Transport demand models and data

Transport demand analysis relies on various models to help predict the consequences of a particular project, programme or policy. These models are a simplified representation of the real world. People involved in demand analysis should understand their capabilities and weaknesses.

Transport demand models are designed to predict the amount and type of travel people would choose in a particular situation, and the effects that transport system changes have on travel activity. For example, a model might predict the number and types of trips generated by a store or school, and how these would be affected by demographic, travel condition and price changes.

These models rely on demographic, travel activity, transport price and land use data. Data sets are often incomplete, inconsistent and outdated. Definitions and methodologies often vary between surveys, making results difficult to compare (May *et al.*, 2008). It can be particularly challenging to obtain reliable data in developing countries.

For a summary of common problems with current transport statistics and models and ways to correct these, see "Transport Model Improvements" at: www.vtpi.org/tdm/tdm125.htm

These improvements are particularly important for evaluating demand management strategies and modelling in developing countries.

Figures 7: TransMusi travel card (left) and ticket machines (right). The fare of public transport is usually adjusted every year to reflect (at least to some extent) inflation.

Source: Palembang (Indonesia), Arimbi, J. (2012) (left); Tokyo (Japan), Broaddus, GIZ Photo Album 2010 (right)

Box 13 Transport elasticities online database

The Australian Bureau of Infrastructure, Transport and Regional Economics (BITRE) offers an excellent online database of transport elasticities, freely available for policy-makers and transport analysts. The database contains at present approximately 200 separate bibliographic references and 400 table entries. Access the database at: www.bitre.gov.au/tedb/index.aspx.

Box 14 Gasoline price-elasticity spreadsheet

Charles Komanoff built an Excel spreadsheet which estimates the price-elasticity of demand for gasoline in the U.S. based on monthly fuel consumption and price data. The results as of early 2009 indicate a short-run elasticity of -0.12 and a long-run elasticity of -0.30.

The spreadsheet can be downloaded here: www.komanoff.net/oil_9_11/Gasoline_Price_Elasticity.xls

Box 15

Commute trip reduction programmes

Models are now available which can predict the travel impacts of a specific Commute Trip Reduction programme, taking into account the type of programme and worksite. These include the *CUTR_AVR Model* (www.cutr.usf.edu/tdm/download.htm), the *Business Benefits Calculator* (BBC) (www.commuterchoice.com) and the *Commuter Choice Decision Support Tool* (www.ops.fhwa.dot.gov/PrimerDSS/index.htm).

Travel impacts are affected by the magnitude of the benefit and the quality of travel options available. Mode shifts tend to be greatest if current public transport use is low. In New York City, where public transport commute rates are already high, public transport benefits only increased public transport use 16% to 23%, while in Philadelphia, public transport commuting increased 32% (Schwenk, 1995).

Figure 8: Bus stop in New York City, where public transport benefits increased public transport use from 16% to 23%. Source: New York City (USA), Gomez Vilchez, J. (2012)



4 Overview of selected transport elasticity values

This section highlights various key transport elasticities that have been estimated through different studies. The aim of the section is to provide a brief overview of different “generic” transport elasticities. For more a more comprehensive survey of transport elasticities, see Box 16.

4.1 Summaries

Table 3 and 4 summarise some transport elasticity studies.

Some countries have adopted standard elasticity values to be used consistently in official models and demand evaluations. Table 5 shows travel elasticity values by purpose of trip.

4.2 Car travel elasticity values

There are various transport elasticity values associated with car travel. They include aspects such as ownership, income, fuel consumption.

Vehicle ownership

Whelan (2007) identified various factors that affect vehicle ownership, including household demographics, income and location. Comparing UK and US travel patterns Johansson and Schipper (1997) conclude that per capita vehicle ownership is affected by fuel prices (elasticity -0.1), income (elasticity 1.0), other taxes (elasticity -0.06), and population density (elasticity -0.4). Goodwin, Dargay and Hanly (2004) estimate that a 10% fuel price increase reduces vehicle ownership 1.0% in the short-run and 2.5% over the long-run.

Box 16

Comprehensive survey of transport elasticities

Numerous studies have investigated transport elasticities (see summaries in BTE Transport Elasticities Database; Glaister and Graham 2002; Goodwin, Dargay and Hanly 2004; Oum, Waters and Yong 1992; Pratt 2004; TRACE 1999; and Wardman and Shires 2011).

For a more comprehensive summary of the results of various transport elasticity studies (reflecting various analysis, scopes and perspectives), see Litman (2011) “Understanding Transport Demands and Elasticities”: www.vtppi.org/elasticities.pdf

Table 3: Transport elasticities (Goodwin 1992)

	Short-Run	Long-Run
Petrol consumption WRT petrol price	-0.27	-0.71
Traffic levels WRT petrol price	-0.16	-0.33
Bus demand WRT fare cost	-0.28	-0.55
Railway demand WRT fare cost	-0.65	-1.08

Table 4: Consumer demand elasticities, European data (Mayeres 2000)

	Price, Peak	Price, Off-Peak
Vehicle travel – essential trips	-0.16	-0.43
Vehicle travel – optional trips	-0.43	-0.36
Bus, Tram, Metro passenger-km	-0.19	-0.29
Rail passenger-km	-0.37	-0.43

This table summarises elasticities from European studies. It indicates greater price elasticities for essential and peak-period travel compared with optional and off-peak travel.

Table 5: European travel elasticities (*de Jong and Gunn 2001*)

Term/ Purpose	Car-Trips WRT Fuel Price	Car-Kms. WRT Fuel Price	Car-Trips WRT Travel Time	Car-Kms. WRT Travel Time
Short Term				
Commuting	-0.20	-0.12	-0.62	
HB business	-0.06	-0.02		
NHB business	-0.06	-0.02		
Education	-0.22	-0.09		
Other	-0.20	-0.20	-0.52	
Total	-0.16	-0.16	-0.60	-0.20
Long Term				
Commuting	-0.14	-0.23	-0.41	-0.63
HB business	-0.07	-0.20	-0.30	-0.61
NHB business	-0.17	-0.26	-0.12	-0.53
Education	-0.40	-0.41	-0.57	-0.76
Other	-0.15	-0.29	-0.52	-0.85
Total	-0.19	-0.26	-0.29	-0.74

WRT = "With Respect To" HB = "Home Based" NHB = "Not Home Based"

Table 6: Estimated long run elasticities

(*Johansson and Schipper 1997*)

Estimated Component	Fuel Price	Income
Car Stock (vehicle ownership)	-0.1	1.0
Car Fuel Demand	-0.7	1.2
Car Travel Demand	-0.3	1.2

Summarises various studies. Numbers indicate original authors' "best guess" values.

Table 7: Summary of elasticity studies

(*Goodwin, Dargay and Hanly 2004*)

Dependent Variable	Short term	Long term
Fuel consumption (total)	-0.25	-0.64
Vehicle kilometres (total)	-0.10	-0.29
Vehicle stock	-0.08	-0.25

This table summarises numerous elasticity studies. The values reflect only the mean elasticity.

Based on a major review of studies, Goodwin, Dargay and Hanly (2004) state that:

- Long run elasticities are greater than short run, mostly by factors of 2 to 3;
- Total vehicle ownership to fall less than 1% in the short run and 2.5% in the longer run.

There is evidence that vehicle travel demand has peaked in most industrialised countries (Millard-Ball and Schipper 2010; Metz 2012). This may make vehicle travel more price sensitive, particularly if the quality of alternative modes improves.

Income

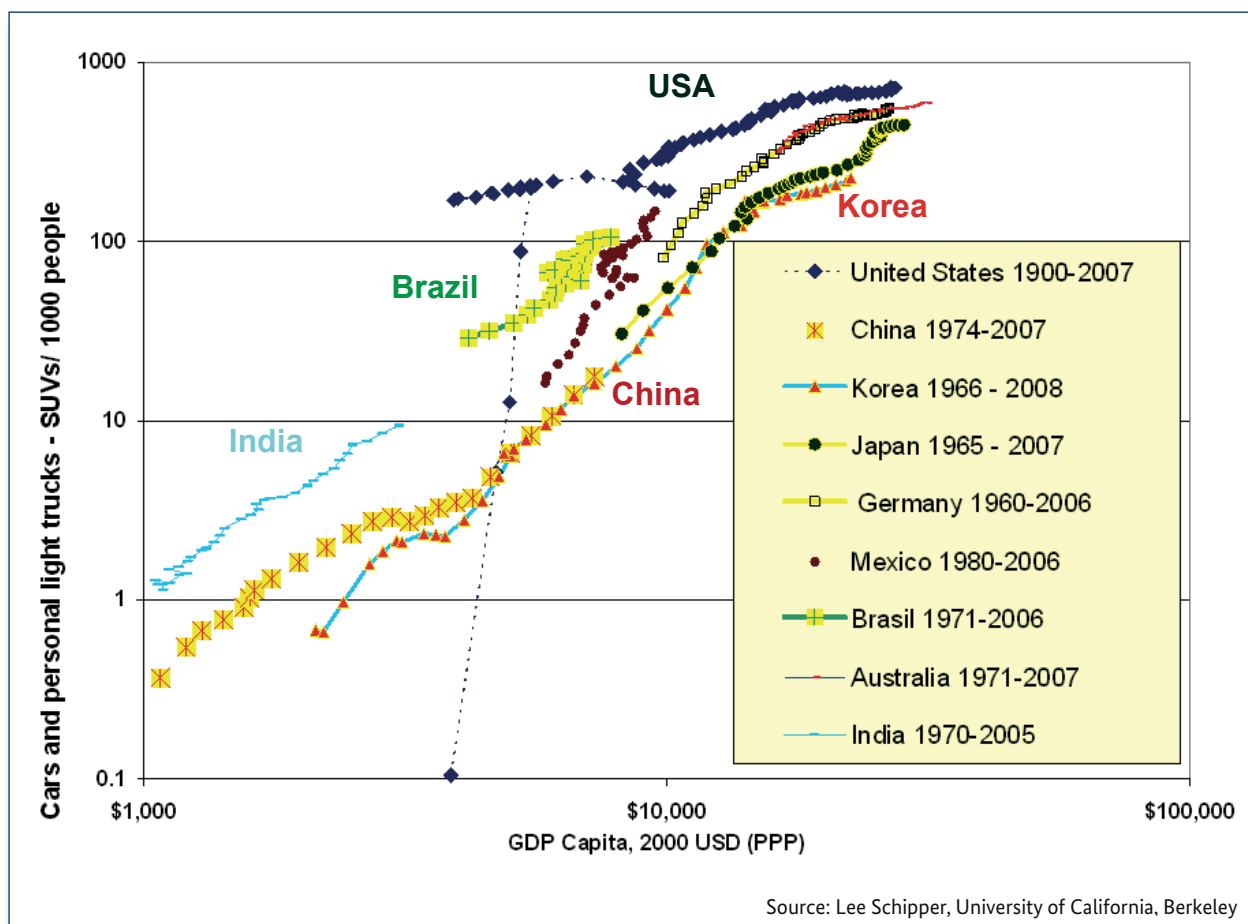
As households become wealthier their vehicle ownership tends to increase, but at a declining rate (Dargay, Gately and Sommer 2007; Millard-Ball and Schipper 2010). If walking and cycling conditions are poor and driving is faster and cheaper than public transport, households tend to own more automobiles.

Dargay and Hanly (2004) conclude that income elasticities are greater than price, mostly by factors of 1.5 to 3.

They also predict that if real income increases 10%, the following occurs:

- Number of vehicles, and the total amount of fuel they consume, will both rise by nearly 4% within about a year, and by over 10% in the longer run.
- Traffic volume (i.e. total vehicle travel) increases about 2% within a year and 5% in the longer run, indicating that the additional vehicles are driven less than average mileage.

As the graph below shows, while motor vehicle ownership tends to rise with income, fuel pricing and other factors can lead to dramatically different ownership rates at the same per capita income. For example, Korea has a level only 1/3 that of the U.S. at the same income.



Graph 4: Motorisation grows with income, but not on a single path.

Source: Schipper, 2009

Fuel consumption with respect to fuel price

Fuel price increases tend to cause fuel consumption to decline in the short-term by reducing total vehicle mileage and traffic speeds, and shifting travel to more fuel-efficient vehicles in multi-vehicle households, and in the long-term by increasing vehicle fuel economy (distance traveled per unit of fuel consumed), and more accessible land use patterns (Institute for Transport Studies 2004; Sterner 2006; Lipow 2008; CBO 2008; Sivak and Schoettle 2009; UKERC 2009). Where fuel prices are low, motorists tend to use improvements in vehicle energy *efficiency*^[5] to increase vehicle performance (power and size) rather than improving fuel economy (Lutsey and Sperling 2005).

Various studies on fuel price impacts on vehicle travel and fuel consumption indicate that fuel price elasticities are around -0.25 in the short-run, and -0.7 in the long-run. Goodwin (1992) predicts that a 10% vehicle fuel price increase will have the following effects:

- In the short run vehicle travel declines about 1.5% and fuel consumption 2.7%, due in part to shifts to more fuel efficient vehicles in multi-vehicle households and reduced speeds.
- In the long run vehicle travel declines 3–5%, split between reduced car ownership and per-vehicle use. Petroleum consumption declines 7% or more, due in part to the purchase of more fuel-efficient vehicles.

^[5] Power per unit of fuel consumed.

Goodwin, Dargay and Hanly (2004) assert that:

- Fuel consumption elasticities are greater than traffic elasticities, mostly by factors of 1.5 to 2.

They predict that a 10% real (inflation adjusted) fuel price increase will cause:

- Traffic volumes to fall about 1% within a year and 3% over the longer run (five years).
- Fuel consumption to fall about 2.5% within a year and 6% over the longer run.
- Vehicle fuel economy to increase about 1.5% within a year and 4% over the longer run.

Thus fuel consumed declines more than vehicle travel because motorists purchase more fuel-efficient vehicles and drive more carefully.

Lee, Han and Lee (2009) found long-run elasticities of vehicle travel with respect to fuel prices to average -0.59 in Korea between 2000 and 2008. This is a relatively high value possibly reflecting high quality travel alternatives.

Table 8 summarises the major results of these fuel price elasticity studies.

Table 8: Summary of fuel price elasticity studies

Study	Study Type	Scope	Major Results
Goodwin, Dargay and Hanly (2004)	Summarised various fuel price and income elasticity studies.	1929 to 1991. Mostly North America and Europe.	-0.25 short run -0.60 long run
Glaister and Graham (2002)	Review of various fuel price and income elasticity studies.	Second half of the Twentieth Century. Mostly North America and Europe.	-0.20 to -0.30 short run -0.60 to -0.80 long run
Lipow 2008	Review of selected energy price elasticity studies.	Second half of the Twentieth Century. Mostly North America and Europe.	-0.17 short run -0.40 long run

Various types of studies covering various times and geographic areas have measured fuel price elasticities. Some of these are reviews of previous studies.

Vehicle travel with respect to fuel prices

As mentioned above, about a third of the fuel savings that result from increased fuel prices consist of reductions in vehicle mileage.

TRACE (1999) provides detailed estimates of the elasticity of various types of travel (car-trips, car-kilometres, public transport travel, walking/cycling, commuting, business trips, etc.) with respect to fuel price under various conditions (level of vehicle ownership, public transport use, type of trip, etc.). Table 9 summarises fuel price elasticities of kilometres travelled, including commuting trips, for various transport modes. The table is based on information on areas with high vehicle ownership (more than 450 vehicles per 1 000 people).

CBO (2008) found that increased fuel prices reduce urban highway traffic speeds and volumes. For each 50¢ per gallon (20%) gasoline price increase, traffic volumes on highways with parallel rail service declined by 0.7% on weekdays and 0.2% on weekends, with comparable increases in public transport patronage.

Regarding rebound effects derived from energy efficiency improvements, Small and Van Dender (2005 and 2007) estimated rebound effects of 4.7% in the short-run and 22% over the long-run. That means that a 10% fuel efficiency gain will increase vehicles miles travelled (VMT) 0.47% in the short-run and 2.2% over the long-run.

Table 9: Elasticities WRT fuel price (TRACE 1999, Tables 8 & 9)

Term/Purpose	Car Driver	Public Transport	Walking and Cycling
Trips			
Commuting	-0.11	+0.20	+0.18
Total	-0.19	+0.13	+0.13
Kilometres			
Commuting	-0.20	+0.22	+0.19
Total	-0.29	+0.14	+0.13

This table shows the estimated elasticities and cross-elasticities of urban travel in response to fuel or other vehicle operating costs. For example, a 10% fuel price increase is predicted to reduce automobile commuting trips by 1% and increase public transport patronage by 2%.

Table 10 summarises the major results of these travel price elasticity.

Table 10: Summary of vehicle travel price sensitivity studies

Study	Study Type	Scope	Major Results
Johansson and Schipper (1997)	Summary of various previous studies	International	-0.2 long run
Goodwin, Dargay and Hanly (2004)	Summarised results of various fuel price and income elasticity studies	1929 to 1991, mostly North America and Europe.	-0.1 short run -0.3 long run
Small and Van Dender (2010)	Vehicle travel elasticity WRT fuel price.	1997–2001, U.S.	-0.026 short run -0.121% long run
Li, Linn and Muehlegger (2011)	Vehicle travel WRT fuel price.	1968–2008, U.S.	-0.24 to -0.34

Various types of studies covering various times and geographic areas have measured the elasticity of vehicle travel with respect to fuel prices.

Road pricing and tolls

Pricing mechanisms such as tolls, road pricing and congestion charging^[6] have an impact on road users. Two major reviews suggest that motorists are relatively sensitive to road pricing (NCHRP 2006; Prozzi, *et al.*, 2009). Spears, Boarnet and Handy (2010) conclude that the elasticity of traffic volumes to tolls is typically -0.1 to -0.45. In other words, a 10% toll increase reduces traffic on that roadway 1.0% to 4.5%, depending on conditions.

Roads with fewer essential trips, more viable alternatives or lower congestion levels tend to have higher elasticities. They find that cordon tolls have reduced traffic volumes 12% to 22% in five major European cities. In Singapore, elasticity values are -0.2 to -0.3, so each 10% increase in the cordon charge reduces traffic volumes 2% to 3%. Arentze, Hofman and Timmermans (2004) found that for commute trips, route and departure time changes are most likely to occur, with smaller shifts to public transport and working at home. For non-commute trips, shifts to cycling also occur.

^[6] These pricing mechanisms mean that motorists have to pay a fee for using a particular roadway or driving in a particular area.



Figure 9: Congested street. Cities around the world are faced with the possibility of introducing road pricing.

Source: Durban (South Africa), Gomez Vilchez, J. (2011)

Box 17 The effectiveness of financial incentives

A state-preference survey of long-distance automobile commuters indicates that financial incentives are the most effective strategy for reducing vehicle trips (Washbrook 2002). A CAD 5.00 per round-trip road toll is predicted to reduce automobile commuting 25%, and a CAD 5.00 parking fee would reduce automobile commuting 20%.

Odeck and Svein Brathan (2008) found that elasticities average -0.54 in the short-run and -0.82 in the long-run at 19 Norwegian toll roads, and that public attitudes toward tolls tend to become more favorable when people understand how revenues will be used.

Road pricing impacts and benefits depend on the price structure. A flat kilometre fee primarily affects social trips and tends to cause total trips to decline and shifts to non-motorised modes. A peak-period fee primarily

affects commute trips, and tends to cause a combination of shifts in time and mode, and working at home.

Mileage and emission charges

Various pricing reforms impose distance-based vehicle fees, including per-mile/kilometre road use and emission fees, and distance-based vehicle insurance and registration fees which prorate existing fixed fees by mileage (for example, a USD 1 200 annual insurance premium becomes 10 cents per vehicle-mile). O'Mahony, Geraghty and Humphreys (2000) found that congestion fees averaging EUR 6.40 per trip for 20 volunteer motorists reduced peak period trips 21.6% and total trips 5.7%, peak mileage 24.8% and total mileage 12.4%. See also Brookings Institution (2008 and 2009).

Parking price

Motorists tend to be particularly sensitive to parking price because it is such a direct charge. Compared with other out-of-pocket expenses, parking fees are found to have a greater effect on vehicle trips, typically by a factor of 1.5 to 2.0 (USEPA 1998). For example, a USD 1.00 per trip parking charge is likely to cause the same reduction in vehicle travel as a fuel price increase averaging USD 1.50 to USD 2.00 per trip.

Frank *et al.*, (2011) conclude that parking pricing can have significant impacts on vehicle travel and emissions. Increasing parking fees from approximately USD 0.28 to USD 1.19 per hour reduced VMT 11.5% and emissions 9.9%.

Hensher and King (2001) model the price elasticity of Central Business District (CBD) parking, and predict how an increase in parking prices in one location will shift cars to park at other locations and drivers to public transport (Table 11).

Hess (2001) assesses the effect of free parking on commuter mode choice and parking demand in Portland's (Oregon) CBD. He found that where parking is free, 62% of commuters drive alone, 16% car-share and 22% use public transport; with a USD 6.00 daily parking charge 46% drive alone, 4% car-share and 50% use public transport. The USD 6.00 parking charge results in 21 fewer cars driven for every 100 commuters, a daily reduction of 147 VMT per 100 commuters and an annual reduction of 39 000 VMT per 100 commuters. TRACE (1999) provides detailed estimates of the elasticity of various types of travel (car-trips, car-kilometres, public transport travel, walking/cycling, commuting, business trips, etc.) with respect to parking price under various conditions (*e.g.* level of vehicle ownership and public transport use, type of trip). Table 12 summarises long-term elasticities for relatively automobile-oriented urban regions.

Travel time

Increased travel speed and reduced delay (by congestion or transfers) tends to increase travel distance, and increased relative speed for a particular mode tends to attract travel from other modes on a corridor. Some research supports the idea that the amount of time people devote to travel tends to remain constant over the years (typically averaging 70–90 daily minutes), implying the elasticity of travel with respect to speed is 1.0

(Mokhtarian and Chen 2004). Leading U.K. transport economists concluded the elasticity of travel volume with respect to travel time is -0.5 in the short term and -1.0 over the long term (SACTRA 1994), so increasing traffic speeds 20% typically increases traffic volumes 10% in the short term and 20% over the long term.

Table 11: Parking elasticities (*Hensher and King 2001, Table 6*)

	Preferred CBD	Less Preferred CBD
Car Trip, Preferred CBD	-0.541	0.205
Car Trip, Less Preferred CBD	0.837	-0.015
Park & Ride	0.363	0.136
Ride Public Transport	0.291	0.104
Forego CBD Trip	0.469	0.150

This table shows elasticities and cross-elasticities for changes in parking prices at various Central Business District (CBD) locations. For example, a 10% increase in prices at preferred CBD parking locations will cause a 5.41% reduction in demand there, a 3.63% increase in Park & Ride trips, a 2.91% increase in public transport trips and a 4.69% reduction in total CBD trips.

Table 12: Parking price elasticities (TRACE, 1999, Tables 32 & 33)

Term/Purpose	Car Driver	Car Passenger	Public Transport	Walking and Cycling
Trips				
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

This table indicates how parking fees affects various types of trips. For example, a 10% increase in commuter parking prices will reduce automobile trips and parking demand 0.8%, and increase car passenger, public transport, and slow mode travel (walking and cycling) 0.2% each.

Table 13: Vehicle travel elasticities with respect to travel time (Goodwin 1996)

	Short Run	Long Run
Urban Roads	-0.27	-0.57
Rural Roads	-0.67	-1.33

Box 18
Induced travel from roadway improvements

Various studies have used the elasticity of travel with respect to travel time to calculate the amount of induced travel that results from roadway improvements that increase travel speeds and reduce delays, particularly expansion of congested urban roadways (Litman, 2001).

For further information, see Schiffer, Steinvorth and Milam (2005).

4.3 Public transport elasticity values

As shown in Box 19, various factors affect public transport elasticities.

Box 19

Factors affecting public transport elasticities

Several factors can affect public transport elasticities (Litman 2004; McCollom and Pratt 2005; Paulley 2004; Pratt and Evans 2004; Taylor *et al.*, 2009; TRL 2004; Wang 2011; Wardman and Shires 2003 and 2011):

- **User type.** Users dependent on public transport are generally less price sensitive than discretionary (also called choice) users, people who could drive for that trip. People with low incomes (at least in North America), disabilities, young and old age tend to be more public transport dependent. In most high income communities public transport dependent people are a relatively small portion of the total population but a large portion of public transport users, while discretionary users are a potentially large but more price sensitive market segment.
- **Trip type.** Non-commute trips tend to be more price sensitive than commute trips. Elasticities for off-peak public transport travel are typically 1.5–2 times higher than peak period elasticities, because peak-period travel largely consists of commute trips.
- **Mode and route.** Rail and bus elasticities often differ. In major cities, rail fare elasticities tend to be relatively low, typically in the -0.18 range due to users with relatively high incomes. For example, the Chicago Transportation Authority found peak bus users have an elasticity of -0.30 , and off-peak users -0.46 , while rail users have peak and off-peak elasticities of -0.10 and -0.46 , respectively. Fare elasticities tend to be lower on routes that serve more people who are public transport dependent and higher on routes where travelers have viable alternatives, such as for suburban rail systems.
- **Geography.** Large cities tend to have lower price elasticities than smaller cities and suburbs, probably reflecting differences in the portion of public transport-dependent residents.
- **Type of price change.** Public transport fares, service quality (service speed, frequency, coverage and comfort) and parking pricing tend to have the greatest impact on public transport patronage. Fuel price tends to have relatively little impact. Elasticities appear to be somewhat higher for higher fare levels (*i.e.* when the starting point of a fare increase is relatively high).
- **Type of public transport.** Slower local buses often have different elasticities than higher speed rail and Bus Rapid Transit (BRT) services because they serve different markets. Although car ownership has a negative impact on rail demand, it is less than for bus and, although there are quite large variations between market segments and across distance bands, the overall effect of income on rail demand is often positive.



Figure 10: Public transport use. Various factors affect public transport elasticities including user type, trip type, mode and route, geography, type of public transport and type of price change.

Source: Tallinn (Estonia), Schmid, D. (2011)

Public transport fare elasticities

Taylor, *et al.*, (2009) evaluated how various geographic, demographic, pricing and public transport supply factors affect per capita public transport patronage rates in US cities. They found a relatively high aggregate (all types of public transport) fare elasticity of -0.51.

Dargay and Hanly (1999) studied the effects of UK bus fare changes over several years to derive elasticity values. They found that demand is slightly more sensitive to rising fares (-0.4 in the short-run and -0.7 in the long-run) than falling fares (-0.3 in the short-run and -0.6 in the long-run), and tends to be more price sensitive at

higher fare levels. The cross-elasticity of bus patronage to automobile operating costs is negligible in the short-run but increases to 0.3 to 0.4 over the long-run, and the long-run elasticity of car ownership with respect to public transport fares is 0.4, while the elasticity of car use with respect to public transport fares is 0.3 (see Table 14).

Based on extensive research, TRL (2004) calculates that bus fare elasticities average approximately -0.4 in the short-run and 1.0 over the long-run, while metro rail fare elasticities are -0.3 in the short-run and -0.6 in the long-run. Bus fare elasticities are lower (-0.24) during peak than off-peak (-0.51).

TRL (2004) calculates generalised cost elasticities to be -0.4 to -1.7 for urban bus, -1.85 for London underground, and -0.6 to -2.0 for rail transport.

Public transport level of service elasticities

Service elasticity refers to how changes in public transport service mileage, service-hours, frequency, and service quality (such as comfort) affect public transport patronage. Public transport patronage tends to be more responsive to service improvements than to fare reductions. Pratt (1999) concludes that “ridership tends to be one-third to two-thirds as responsive to a fare change as it is to an equivalent percentage change in service”,

Table 14: Bus fare elasticities

(Dargay and Hanly 1999, p. viii)

Elasticity Type	Short-Run	Long-Run
Non-urban	-0.2 to -0.3	-0.8 to -1.0
Urban	-0.2 to -0.3	-0.4 to -0.6

This table shows elasticity values from a UK study.

particularly by discretionary travellers (people who could drive).

Evans (2004) provides various public transport service elasticities. The elasticity of public transport use to service expansion is typically 0.6 to 1.0, meaning that each 1% increase in public transport vehicle-miles or -hours increases patronage 0.6–1.0%. The elasticity of public transport use with respect to service frequency (called a headway elasticity) averages 0.5^[7].

Pratt (1999) finds that completely new bus service in a community that previously had no public transport service typically achieves 3 to 5 annual rides per capita, with 0.8 to 1.2 passengers per bus mile. Improved schedule information, easy-to-remember departure times (for example, every hour or half-hour), and more convenient transfers can also increase public transport use, particularly in areas where service is less frequent. Taylor, *et al.*, (2009) found service elasticities with respect to vehicle hours of 1.1 to 1.2.

Mackett (2000 and 2001) identifies a number of positive incentives that could reduce short (under 5 mile) car trips, including improved public transport service, improved security, reduced public transport fares, pedestrian and cycling improvements. Of those, public transport improvements are predicted to have the greatest potential travel impacts.

Table 15 shows estimated price and cross fare elasticities for various modes (bus, taxi, car) both at peak and off-peak times in Australia.

Lee, Lee and Park (2003) surveyed motorists to determine factors that affect their willingness to shift to public transport. Motorists are more sensitive to parking fees, travel time and crowding, indicating that public transport service improvements can increase discretionary users patronage.

^[7] There is a wide variation in these factors, depending on specific conditions. Higher service elasticities often occur with new express public transport service, in university towns, and in suburbs with rail stations to feed. It usually takes 1 to 3 years for patronage on new routes to reach its full potential.

Table 15: Australian travel demand elasticities

(Booz, Allen Hamilton 2003)

Mode	Peak	Off-Peak	Total
Bus	-0.18	-0.22	-0.20
Taxi	0.03	0.08	0.07
Car	0.01	0.01	0.01

This table shows elasticity and cross-elasticity values. It means, for example, that a 10% peak-period public transport fare increase (decrease) will reduce (increase) peak-period public transport patronage by 1.8%, and will increase (reduce) taxi travel by 0.3% and car travel by 0.1%.

4.4 Modal shifts: transport elasticity and cross-elasticity values

Cross-elasticity values refer to, for example, changes in car travel due to public transport fare changes, changes in public transport patronage due to changes in car operating costs, or changes in one type of public transport (such as bus) in response to price changes in another type of public transport (such as rail). Table 16 shows own (direct) and cross-elasticity values for train, bus and car.

TRACE (1999) estimates that a 10% fuel price increase causes public transport patronage to increase 1.6% in the short run and 1.2% over the long run (this declining elasticity value is unique to fuel, due to motorists purchasing more efficient vehicles when fuel prices rise) (Table 16).

Frank, *et al.*, (2008) find that the relative travel time between different modes significantly affects mode choice. Increasing drive alone commute time by 10% was associated with increases in demand for public transport by 3.1%, bike demand by 2.8% and walk demand by 0.5%. Public transport users are found to be more sensitive to changes in travel time, particularly waiting time, than to cost of public transport fares. Increasing public transport in-vehicle travel times for non-work travel by 10% was associated with a 2.3% decrease in public transport demand, compared to a 0.8% reduction for a 10% fare increase. Non-work walking trips increased in more walkable areas with increased density, mix and intersection density. Increasing auto travel time for non-work trips by 10% was associated with a 2.3% increase in public transport patronage, a 2.8% increase in bicycling, and a 0.7% increase in walking. Walking and biking are used for shorter trips, such as travel to local stores and mid-day tours from worksites if services are nearby.

Table 16: Direct and cross-share elasticities (Hensher 1997, Table 8)

	Train Single Fare	Train Pass	Bus Single Fare	Bus Pass	Car
Train, single fare	-0.218	0.001	0.057	0.005	0.196
Train, pass	0.001	-0.196	0.001	0.001	0.335
Bus, single fare	0.067	0.001	-0.357	0.001	0.116
Bus, pass	0.007	0.001	0.001	-0.098	0.020
Car	0.053	0.003	0.066	0.003	-0.197

This table indicates how public transport fare and car operating cost changes affects public transport and car travel demand. For example, a 10% increase in single fare train tickets will reduce the sale of those fares 2.18% and increase single fare bus ticket sales 0.57%.

METS (MEtropolitan Transport Simulator)^[8] uses default values (see Table 17) that simulate transport in London.

Each row indicates how demand for that form of transport changes as costs (fares and travel time) change. For example, the first number indicates that the own-price elasticity of demand for car journeys is -0.3, so a 10% car cost increase reduces car use 3%. The second number (0.09) is the cross-price elasticity of demand for car use with respect to bus costs: a 10% increase in bus costs would cause a 0.9% car use increase. The third number (0.057) is the cross-price elasticity of car use with respect to Underground costs.

Table 17: METS cost elasticities

	Car	Bus	Underground
Car	-0.30	0.09	0.057
Bus	0.17	-0.64	0.13
Underground	0.056	0.20	-0.50

Source: Grayling and Glaister p.35.

^[8] Tackling Traffic Congestion: More about the METS Model, Virtual Learning Arcade (www.bized.co.uk/virtual/vla/transport/resource_pack/notes_mets.htm).

Box 20: Fuel prices and fuel consumption: German experience

The elasticity values (both short-run and long-run) of fuel consumption WRT fuel price from various studies have been stated in the previous section. In general, the elasticity of fuel consumption WRT fuel price is estimated to be -0.25 in the short-run and -0.7 in the long-run. The fuel price structure and the evolution of fuel prices and fuel consumption in Germany's road transport sector in recent years are shown below.

Fuel price structure in Germany

In February 2012, the retail (pump) prices of petrol (unleaded Euro 95) and diesel in Germany were EUR 1.584 and EUR 1.460 per litre, respectively. This retail price can be broken down, as it is shown in Table 18.

	Petrol (unleaded Euro 95)	Diesel
Purchase price of crude oil	€ 0.546	€ 0.546
Industry margin	€ 0.136	€ 0.211
Excise duties	€ 0.649	€ 0.470
Value Added Taxes (VAT)	€ 0.253	€ 0.233
Retail price	€ 1.584	€ 1.460

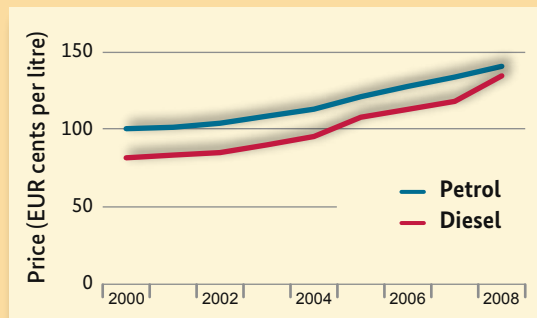
*Data from the 7 February 2012
Source: EU Energy Portal (2012)

Therefore, it can be seen that fuel taxation represents in Germany 57% of retail price for petrol and 48% for diesel.

Fuel prices in Germany (2000–2008)

In Germany, fuel prices have increased between the year 2000 and 2008. Graph 5 illustrates the price trend for petrol and diesel fuels during this period.

Graph 5: Nominal petrol (unleaded) and diesel fuel prices in Germany (2000–2008)



Source: Own work based on Mineralölwirtschaftsverband (MwV) <http://www.mwv.de/index.php/daten/statistikenpreise/?loc=8>

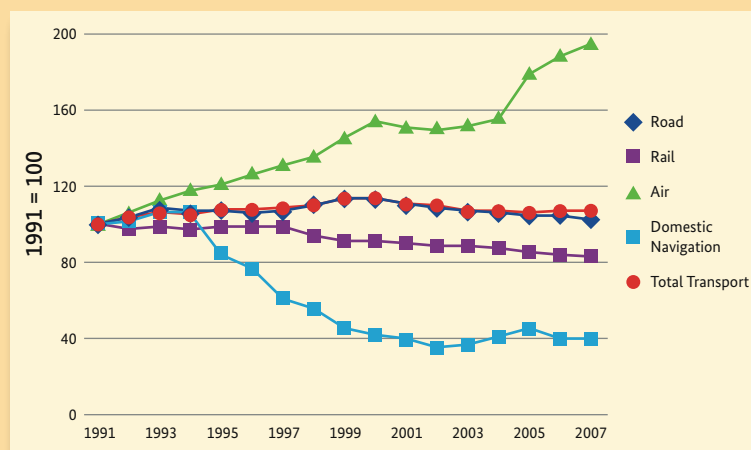
The graph shows how these fuel prices have increased in recent years. Between the year 2000 and 2008, the price of petrol fuel increased by around 41%, from 0.993 to EUR 1.397 per litre. Regarding diesel, its price has also increased from EUR 0.804 per litre in 2000 to EUR 1.335 per litre (66% increase). It can clearly be seen that the price gap between both fuels has decreased during this period.

The significant increase in fuel prices in Germany may be explained by the increase in world oil prices as well as by the specific actions that the German government has implemented to ensure a more efficient use of energy resources, contributing to environmental goals.

Energy consumption in Germany's transport sector (2000–2007)

In Germany, transport energy consumption slightly decreased between 2000 and 2007. Graph 6 shows the development of transport energy consumption between 1991 and 2007, by mode of transport (Schlomann *et al.*, 2009).

Graph 6: Transport energy consumption by mode of transport in Germany (1991–2007)



Source: Schlomann *et al.*, (2009)

As can be seen, between 2000 and 2007 only air transport increased its energy consumption. The road transport sector, which accounts for approximately 80% of the modal share, decreased its energy consumption during the same period. However this change was different for gasoline and diesel vehicles: indeed diesel cars increased their energy consumption during that period (Schlomann *et al.*, (2009)).

Despite the increase in fuel prices between 2000 and 2008, the statistics of OECD/ITF show that inland passenger road traffic (passenger-km (pkm)) for private cars increased in Germany from 831 300 M pkm in the year 2000 to 871 300 M pkm in 2008. Thus it is reasonable to state that fuel efficiency gains in passenger vehicles were achieved during this period.

Finally, the extent to which this decrease in fuel consumption in the German road transport sector can be explained by an increase in fuel prices during the period under consideration needs to be further investigated.

In conclusion, economic instruments such as fuel taxation (which, as shown above, is particularly high in Germany) have an important role to play to encourage a more rational and efficient use of transport energy. Other supportive measures, including regulatory instruments such as fuel standards, can also substantially contribute to the promotion of cleaner transport. Thus countries that effectively manage to implement those measures can reap the benefits of low-carbon sustainable transport.

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5 Conclusions and policy recommendations

Travel demand refers to the amount and type of travel that people would choose in particular situations. Models that reflect these relationships can predict how various trends, policies and projects will affect future travel activity, and therefore evaluate potential problems and transport system improvement strategies.

Prices are the direct, perceived costs of using a good. Transport prices can include monetary (money) costs, plus travel time, discomfort and risk. Price changes can affect trip frequency, route, mode, destination, scheduling, vehicle type, parking location, type of service selected, and location decisions. Pricing impacts are commonly measured using elasticities, the percentage change in consumption (in this case, in travel activity) that results from each 1% change in price.

A considerable body of research has analysed how transport price changes affect transport activity, including changes in fuel prices, road tolls, parking fees, fares, and transport service quality, for various modes, user groups and travel conditions. Although these impacts vary widely, it is possible to identify certain patterns which allow these relationships to be modelled. For example:

- Transport pricing impacts can vary, including changes in trip generation, mode, destination, route, vehicle type and parking location. Pricing of one mode or service can affect demand of others.
- Pricing impacts tend to increase over time, and are typically triple over the long-run.
- Higher value travel, such as business and commute travel, tend to be less price sensitive than lower value travel.
- Wealthy people tend to be less sensitive to pricing and more sensitive to service quality than lower-income people.
- Travel tends to be more price sensitive if travellers have better travel options and perceive a larger viable alternative choice set.
- Motorists tend to be particularly sensitive to road tolls and parking fees.

- How fees are promoted, structured and collected, as well as when, where, how often, and how fees are collected, can affect their impacts.
- Motorists are more likely to accept vehicle price increases if presented as part of an integrated programme that is considered fair and provides dispersed benefits.

A key factor in this analysis is the degree to which the demand factors and elasticity values collected in past studies are transferable to different times and places. The basic relationships that affect travel demands tend to be durable and therefore transferable, but it is important to take into account factors such as differences in employment rates, incomes, transport options and land use patterns when applying past experience in new areas. The values described in this report provide a reasonable starting point for travel demand modelling but they must be calibrated to reflect specific conditions. As transport planners, economists and modellers gain experience we will be better able to develop models for new locations, modes and pricing reforms.

As normally measured, car use appears to be inelastic, meaning that price changes cause proportionately smaller changes in car travel. However, this reflects how price impacts are normally evaluated. Short-run price effects are about a third of long-run effects, and most vehicle costs (depreciation, financing, insurance, registration fees and residential parking) are fixed. A -0.1 short-run elasticity of vehicle travel with respect to fuel price reflects a -0.3 long-run elasticity, which reflects a -1.2 elasticity of vehicle travel with respect to total vehicle costs, which implies that car travel is overall elastic.

Changes over time also alter elasticity values. For example, car travel elasticities declined significantly in the U.S. during the last five decades, due to demographic and economic trends, including rising employment rates, increasing real incomes, declining fuel prices, highway expansion and sprawled land use development, and

declining alternatives. However many of these trends are now reversing, resulting in peaking demand for car travel and increasing demand for alternative modes in most wealthy countries. These trends are increasing the price elasticity of car travel.

This has important implications for developing countries. Countries that implement policies that favour car travel during the early stages of their development, including low prices for fuel, roads and parking, will tend to create automobile dependent transport systems, imposing greater economic, social and environmental costs. Developing countries that implement more efficient prices that test consumers' travel demands will

have more efficient transport systems and fewer associated problems.

Improved transport demand models are important tools to help policy-makers and planners evaluate transport problems and potential solutions. It will be important for developing countries to establish data collection and capacity building programmes to support model development. This can start with for example raising awareness campaigns on the benefits and availability of different transport options and their real costs as well as with trainings on how to measure price sensitivity, with the aim of promoting more sustainable transport options.

6 Selected references and further reading

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