CHAPTER 2

LITERATURE REVIEW

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2.0 Introduction

A sound understanding of road user responses to changes in costs of travel is crucially important in making transport policy decisions. Such information will provide an approximate assessment of the impact on travel demand associated with policy measures under consideration. For example the effectiveness of a fare subsidy policy in inducing demand for travel by public transportation depends largely on the price sensitivity of the road user. Such sensitivity is measured using elasticity.

Due to its importance, a great deal of attention has been devoted to the study of elasticity in associated with road traffic demand. According to Graham (2004), elasticity estimates provide knowledge of how traffic levels might be manipulated by making some changes in the cost of driving. It also help public policy makers reach decision about the allocation of investment and can be used to forecast how the demand for fuel and road travel will change as the costs of travel change.

This chapter discusses the concept and definition of elasticity in general as well as some special concepts of elasticity which are related to the transportation realm. Some empirical findings of price and service elasticity of transport demand are also discussed.

2.1 Elasticity

2.1.1 Definitions

In general, elasticity is the ratio of the relative change in a dependent variable to the relative change in an independent variable (Watson 1982). The concept was originally put forward by the British economist, *Sir Alfred Marshall.* It is a dimensionless measure of sensitivity, which means that the unit of measurement of the variables does not make a different, where the elasticity value will be the same regardless of how the variables are expressed (TRACE 1998).

In the case of demand, elasticity is defined as the percent change in quantity demanded in response to a one percent change in price (Oum et al. 1990). This is known as 'own-price' elasticity. The own-price elasticity of a certain goods or services is usually has a negative value which reflects the inverse relationship between the quantity demanded and its price.

The degree of price sensitivity refers to the absolute elasticity value which could take the range of zero to infinity. Unit elasticity refers to elasticity with an absolute value of 1.0. Such elasticity indicates that price changes caused a proportional change in consumption. If the absolute value of the own-price elasticity is greater than one, the demand is said to be price elastic, which means for a given percentage increase in price causes a larger percentage decline in the quantity demanded. Conversely, if the demand is inelastic, the percentage change in quantity demanded is smaller than the percentage change in price. The inelastic demand is represented by the absolute elasticity values less than one.

Several characteristics influence the elasticity of demand for a certain goods. The elasticity of a certain commodity depends largely on whether the good is easily substituted or not. The degree of substitutions will have certain amount of impact on consumer response towards any change in price of the commodity. The share of income spent on the good also will have certain influence on the elasticity value. Theoretically, if a good represents a large share of the consumer's budget, change in the price of the good has a substantial impact on the quantity demanded by the consumer. Other factor affecting the elasticity of demand is the time period. In the long run, there are more possibilities to react, so demand will be more elastic. In the case of demand for car travel, long run reactions may be changes in car ownership, in trip destination or in the residential location (TRACE 1998).

Apart from the own-price elasticity, another important measure of elasticity is cross-price elasticity. Cross-price elasticity refers to the percentage change in the consumption of a good resulting from a price change in another related good (Litman et al. 2004). For example, the parking space is a complementary service to automobile while transit travel is its substitute.

Contrary to the own-price elasticity, for cross-price elasticity the sign of the coefficient is important for it signal whether the related goods are complements or substitutes. If the goods are positively related, then the goods are apparently substitutes to each other. Whereas, a negative coefficient signifies that the goods are complements.

2.1.2 Some Basic Elasticity Concepts

According to Oum T.H et al. (1992), there are number of different concepts which are important for understanding transport demand elasticities and they lie within the general notion of elasticity of demand. These concepts are discussed below.

a) Ordinary and compensated demand elasticities.

Economists distinguish between two concepts of price elasticities: ordinary demand elasticity and compensated demand elasticity. For a consumer demand, a change in price has two effects, a substitution effect and an income effect. The substitution effect is the change in consumption in response to the price change, holding real income (utility) constant (Oum et al. 1990:2). While the income effects occurs as change in price will affect the consumer's real income, and will affect the consumer's demand for all goods.

The ordinary price elasticity measures both substitution and income effects. The ordinary elasticity is derived from the ordinary or Marshallian demand. This demand function is derived by maximizing a representative consumer's utility function subject to a budget constraint. Formally, the ordinary demand is

$$d(p, y, s, \varepsilon) = \underset{x}{Max}[U(x, s, \varepsilon) \quad \text{s.t } x \in B(p, y)],$$

where x is a vector of goods and services, s is vector of observed socio-economic characteristics of the consumer, ε is a vector of unobserved variables and $B(p,y)$ is the consumer's budget constraint which is a function of price (p) and income (y) (Oum T.H et al. 1992). $\in$ denotes that x is an element of the consumer's budget constrain.

On the other hand, the compensated demand elasticity is derived from compensated or Hicksian demand, which is derived by minimizing the consumer's expenditure for achieving a given utility level. Formally, the compensated demand function takes the form of

$$h(p, u, s, \varepsilon) = \underset{x}{Min}[px \quad \text{s.t } U(x, s, \varepsilon) \geq u].$$

The compensated price elasticity measures only the substitution effect of price change since the utility level is held constant in the case of compensated demand function.

According to Oum, T.H et al. (1990), the passenger demand models normally are derived by maximizing, explicitly or implicitly, the utility function subject to the budget constraint. Therefore, these give the ordinary price elasticity, i.e. it encompasses both substitution and income effects. Besides, the compensated demand is a function of utility which is not directly observable, make it practically not estimable.

b) Aggregate market, mode-specific, and mode-choice elaticities.

The market demand refers to the demand for transport relative to other non-transport sectors of the economy. The price elasticity of demand for individual modes is related to but different from the market elasticity of demand. According to Oum T.H et al. (1992), under usual condition[5], the linkage between mode-specific elasticities (own-price elasticity F_{ii} and cross-price elasticity F_{ij}) and the own-price elasticity for aggregate transport demand, F, is:

$$F = \sum_i S_i (\sum_j F_{ij})$$

where S_i denotes the volume share of mode i[6]. The relationship indicates that the aggregate elasticity is lower, in absolute value, than the weighted average of the mode-specific own-price elasticity since the cross-price elasticities generally are positive because of competition between modes.

The concepts of demand elasticities for transportation are further complicated by mode choice (also known as mode split or volume share) elasticity, which should be distinguished from the regular demand elasticities. Mode-choice studies are studies which examines shares of fixed volume of traffic among modes (Oum et al. 1992). Many of the transportation demand studies are mode-choice studies using disaggregate discrete choice models. Oum T.H et al. (1992) pointed out that the aggregate mode-choice studies produce elasticities between modes but they differ from the demand elasticities discussed earlier as they do not take into account the effect of a price change on the aggregate volume of traffic.

[5] That is, conditions for the existence of a consistent aggregate.
[6] In the case of two-mode, the relationship becomes $F = S_1(F_{11}+F_{12}) + S_2(F_{21}+F_{22})$.

It is possible to derive mode-choice elasticities from regular demand elasticities but this entails loss of information, and thus would rarely be a useful practice (Taplin, 1982). Because ordinary price elasticity is generally more useful than mode split elasticities, it is desirable to convert mode-split elasticities to ordinary demand elasticities[7].

c) Short-run and long-run elasticities

It is also important to distinguish between short and long run elasticities. Normally the elasticities of demand in the long-run tend to be higher since in the long-run, consumers are better able to adjust to price signals than in the short-run. As pointed out by Oum T.H et al. (1992), in the long-run, consumers are able to vary their location choice and asset holding, whereas in the shorter period these are not possible. Thus, a long-run demand model should ideally model consumers' location choice and asset ownership together with their transport demand. These are particularly important for long-run policy planning since major changes in transport policy are likely to affect consumers' asset ownership and location choice. These decisions, in turn, will have significant impacts on transport demand (Oum et al. 1992). However, to model a long-run demand for transport requires enormous data and involve complexity in explicitly modeling transport decisions, asset ownership and location choice jointly. These restrictions have resulted in the non-existence of such transport demand model.

[7] Refer Appendix B for this application.

d) Linkages between concepts of demand elasticities.

Figure 2.1 illustrates the summary of concepts of transport demand elasticities and relationships between them. The elasticity of aggregate market demand (*F*) is decomposed into mode-specific demand elasticities, F_{ii}, F_{ij} and F_{jj}. Disaggregate discrete choice models depicted on the right side of the figure. Subject to potential sampling and aggregation errors, the aggregated elasticities derived from discrete choice models can be regarded as estimates of the corresponding aggregate elasticities.

Oum T.H et al. (1992) pointed out that it is worth noting that a discrete choice model using trip diaries as the data base can capture the stimulation effect on total demand of a lower price if those who participated in the survey represent a true random sample of the population and the researcher incorporates the trip frequency information explicitly in the model. The resulting elasticity estimates (properly aggregated) should then approximate the regular demand elasticity. On the other hand, discrete choice model which do not include information on non-travelers produce elasticity estimates which approximate aggregate mode-choice elasticity.

Although it is possible conceptually to link aggregate and disaggregate transport demand elasticities, the two approaches continue to evolve empirically with few comparisons between the two (Oum et al. 1992).

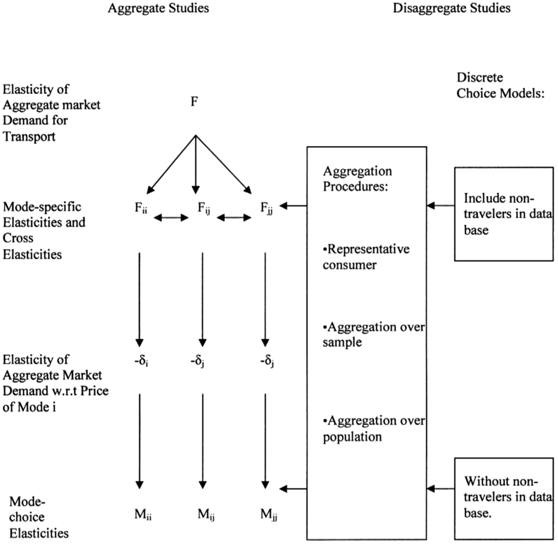

Figure 2.1: A schematic of Concepts and Empirical Approaches to Estimation of Transport Demand Elasticities

2.2 Summary of Elasticity Studies

Many past studies had focused on the price elasticity of public transport and as shown by TRACE (1999), Goodwin (1992), Goodwin et al. (2004), Oum T.H et al. (1990) and Litman et al. (2004). Most of the studies on transport demand elasticities were done in Europe and United States, while a study of estimating price and service of elasticities in Korea was done by Lee et al. (2002).

TRACE (1999)[8] project focuses on the impact of changes in car cost and car travel time, investigating the impact of such changes on demand on car travel and on other travel modes, both for short and long run. The project is based on over 50 studies restricted to countries in Europe, and focuses on recent studies. Comprehensive sets of elasticity values such as these can be used to model the travel impacts of various combinations of price changes, such as a reduction in transit fares combined with an increase in fuel taxes or parking fees.

[8] TRACE is a comprehensive research program, carried out by a consortium of European consultants, and University (ARPA from Italy, Hague Consulting Group from the Netherlands, Heusch/Boesefeldt from Germany, Stratec from Belgium and the University of Cergy-Pontoise from France), which started in January 1998 with the financial support of the European Commission.

Table 2.1:
Commuting elasticities of the number of trips, by modes

	Fuel price		Car time		Parking	
Modes	Short term	Long term	Short term	Long term	Short term	Long term
Car driver	0.08 - 0.32	0.08 - 0.32	0.20 - 0.82	0.23 - 0.90	0.04 - 0.16	0.04 - 0.18
Car passenger	0.26	0.04 - 0.18	0.48	0.77 - 1.07	0.04	0.00 - 0.02
Public transport	0.13 - 0.78	0.05 - 0.36	1.00 - 4.00	0.42 - 1.68	0.02 - 2.00	0.00 - 0.84
Slow modes	0.11	0.04 - 0.15	0.25	0.30 - 0.67	0.04	0.00 - 0.02

Note: Elasticity estimates for car driver and car passenger are in negative values.

Source: TRACE, 1998

Table 2.2:
Commuting elasticities of the number of kilometers, by modes

	Fuel price		Car time		Parking	
Modes	Short term	Long term	Short term	Long term	Short term	Long term
Car driver	0.15	0.20 - 0.35	0.48	0.96 - 1.21	0.02	0.04 - 0.05
Car passenger	0.31	0.05 - 0.20	0.51	1.02 - 1.25	0.02	0.00 - 0.01
Public transport	0.27	0.05 - 0.22	2.09	0.37 - 0.70	0.01	0.00 - 0.01
Slow modes	0.16	0.04 - 0.19	0.29	0.24 - 0.50	0.03	0.00 - 0.02

Note: Elasticity estimates for car driver and car passenger are in negative values.

Source: TRACE, 1998

TRACE study found that the demand for travel tends to be irresponsive to fuel price changes. It estimates that a 10 percent rise in fuel price decrease the demand for travel by private vehicle by 0.8 to 3.2 percent in short run and in the longer period. The same increment in price will induce the mass transport usage by 2.7 percent in short run and the response will be lower in the long run (between 0.5 and 2.2 percent). This pattern of response is unique to fuel, because fuel price increases cause motorist to purchase more fuel-efficient vehicles.

Parking prices tend to have a greater impact on transit demand. A 10 percent increase in parking fee will increase demand for public transport up to 20 percent. The response however will reduce through time as in the long run, the demand for public transport will increase only up to 8.4 percent.

Goodwin (1992), made a detailed review of international studies using time series method, produced the average elasticity values that quantify the response for travel demand of public and private transportation modes with respect to related cost changes. He noted that price impacts tend to increase over time as consumers have more option in a longer time period, which is related to increases in real incomes, automobile ownership, and now telecommunications that can substitute for physical travel (Litman et al. 2004).

However, the elasticity values of demand for car ownership with respect to general public transportation cost ranged from 0.1 to 0.3 depict that any policy measure taken to influence the use of private mode by reducing the public transport fare will not give a favorable result. The same study found that the elasticity of the traffic levels with respect to petrol price is inelastic, where the value is -0.16 in the short run and -0.33 in the long run. This implies that the increase in petrol price will not reduce people preferences toward the private transportation mode.

Table 2.3:
Transportation Elasticities

	Short run	Long run	Not defined
Bus demand with respect to fare cost	-0.28	-0.55	
Railway demand with respect to fare cost	-0.65	-1.08	
Public transit with respect to petrol price			0.34
Car ownership with respect to general public transport costs			0.1 - 0.3
Petrol consumption with respect to petrol price	-0.27	-0.71	-0.53
Traffic levels with respect to petrol price	-0.16	-0.33	

Source: Goodwin, 1992

A review of elasticity estimates of road traffic and fuel consumption with respect to price and income was made by Goodwin et al (2004) using more recent empirical studies. They reviewed 69 new empirical studies, published since 1990, which produced different elasticity values. The range of results was calculated using computer database and the main results from their review are shown in the next table.

Table 2.4:
<u>Elaticities of various measures of demand with respect to fuel price per litre.</u>

Dependent Variables	Short term	Long term
Fuel consumption (total)	-0.25	-0.64
Fuel consumption (per vehicle)	-0.08	-1.10
Vehicle-km (total)	-0.10	-0.29
Vehicle-km (per-vehicle)	-0.10	-0.30
Vehicle stock	-0.08	-0.25

Source: Goodwin et al. (2004)

The Goodwin et al. (2004) study found that the price changes will give a bigger impact on volume of fuel consumed than the volume of traffic. Given a 1o percent increase in real fuel rice, volume of fuel consumed will fall by about 2.5 percent in short run and by 6 percent in a longer period. Meanwhile, reduction in volume of traffic is only around 1 percent in short run, and by 3 percent in long run, given the same reduction in fuel price. Goodwin et al. (2004) argued that this observation is probably because price increases trigger a more efficient use of fuel, such as technical improvements to vehicles, more fuel-conserving driving styles and driving in easier traffic conditions.

Further, the study also found that the same percentage of fuel price increment will caused the efficiency of the use of fuel to rise by about 1.5 percent in short run, and around 4 percent in the longer run, while the number of vehicles owned fell by less than 1 percent in the short run, and by 2.5 percent in the longer period of time. This implies that the sensitivity of car ownership with respect to fuel price is rather large and important enough to take seriously, but Goodwin et al. (2004) believed that it is not necessarily such an overwhelmingly large part of the overall effect.

The most important conclusion made by Goodwin et al. (2004) from their study is that the effects of price on traffic levels were bigger than had been assumed in earlier forecasts, and that these elasticities did not appear to decline over time.

Litman et al. (2004) study was devoted to study the public transportation demand elasticities and they calculate the price and cross price elasticities for public transit using previous research on transit elasticities. The next table presents the recommended transit elasticity values summarizes by Litman et al. (2004).

Table 2.5:
Recommended Transit Elasticity Values

	Market Segment	Short Term	Long Term
Transit ridership with respect to transit fares	Overall	-0.2 to -0.5	-0.6 to -0.9
Transit ridership with respect to transit fares	Peak	-0.15 to -0.3	-0.4 to -0.6
Transit ridership with respect to transit fares	Off-peak	-0.3 to -0.6	-0.8 to -1.0
Transit ridership with respect to transit fares	Suburban commuters	-0.3 to -0.6	-0.8 to -1.0
Transit ridership with respect to transit services	Overall	0.50 to 0.7	0.7 to 1.1
Transit ridership with respect to auto operating costs	Overall	0.05 to 0.15	0.2 to 0.4
Automobile travel with respect to transit costs	Overall	0.03 to 0.1	0.15 to 0.3

Source: Litman, 2004

One important conclusion drawn by Litman et al. (2004) is that no single transit elasticity value applies to all situations. Various factors affect price sensitivities including type of user and trip, geographic conditions and time period. They suggest that the elasticity of transit ridership with respect to fares is usually between -0.2 and -0.5 in the short run and increases to -0.6 to -0.9 over the long run. Litman et al. (2004) argue that a relatively large fare reduction is generally needed to attract motorist to transit, since they are discretionary riders, which according to Litman et al. (2004), may be more responsive to service quality and higher automobile operating costs through road or parking pricing. This fact might reflect the elasticity of transit ridership with respect to transit service which is higher compared to the transit fare effect.

The study also found that the automobile travel with respect to transit cost is very inelastic, ranging from 0.03 to 0.3 for both short and long periods. The same feature for public transit travel demand with respect to automobile operating cost, where the elasticity values are very low (0.05 to 0.4). On the other hand, policies implemented to influence transit ridership by influencing transit fare and service tends to be more effective in the longer period.

In passing, most of the studies are from developed countries. Although the empirical estimates of price and cross price elasticities are expected to be relevant to developing countries as well, it is subject to some caveats. According to Oum T.H et al. (1990), the general caveat is that specific values for elasticities can vary significantly from one market situation to another. Therefore, considerable cautions must be made in generalizing from one situation to another whether it is in a developed or developing country. Secondly, a likely difference is that the degree of intermodal competition generally is much less intense in developing countries. In addition, the price elasticity of demand may differ according to income levels.

A research done by Lee et al. (2002), using 662 people using Stated Preference survey method conducted in the Seoul Metropolitan Area found that the elasticity of passenger car travel with respect to fuel price was estimated to be within -0.078 to -0.0171 range, which reflects that the car demand in Korea is very irresponsive to the raises in fuel price. Meanwhile, the car users' responsiveness to changes in parking costs was estimated to be much higher than fuel costs, as shown in finding from TRACE (1999).

Table 2.6:
Price and Service Elasticities of Private Transportation

	Elasticity estimates
Fuel price elasticity	-0.078 to -0.171
Fare (cross price) elasticity	0.016 to 0.087
In-vehicle (cross) time elasticity	0.459 to 0.545
Out-vehicle (cross) time elasticity	0.197 to 0.377

Source: Lee et al., 2002

On the other hand, the research by Lee et al. (2002) found that the parameter of fare variables was estimated to be statistically insignificant in every sub-group of car users. This suggests that fare policies are relatively ineffective for increasing transit modal shares. However, Lee et al. (2002) suggested that the effect of complete transit fare subsidy needs to be analyzed in the future since the elasticity might show different magnitude in the very high levels of price or fare changes.

A more specific Malaysian case study was done by Morikawa et al. (2003). They analyze the travel behavior of four Asian cities, i.e. Bangkok, Kuala Lumpur, Manila and Nagoya. Using Multinomial Logit (MNL) model, the study studies several attributes affecting travel behavior such as travel time, gender, age, income and occupation which are appropriately included in the choice models. The total 1530 observations were made for the case of Kuala Lumpur, the estimation results show that, as expected, the coefficient for travel time is significantly negative (-0.41). The study also concluded that having driver's license encourages travelers to use car and motorcycle as the estimated parameter is significantly positive. In terms of preference towards public transportation, the study found that travelers in Kuala Lumpur who are 45 and above years old dislike bus transport, and they may prefer taxi or other paratransit for their travel. The same travel behavior was observed in Bangkok and Manila cases. However, the study made no elasticity estimations.

Table 2.7:
Parameter Estimation Results for Kuala Lumpur.

Variables	Parameter Estimates
Alternative specific constants	
Bus constant	1.41 (16.55)
Car constant	-0.39 (-8.45)
Level-of-service variables	
Travel time (hours)	-0.41 (-3.24)
Alternative specific dummies	
Male (car, motorcycle)	0.78 (7.88)
Age $\geq$ 18 (car, motorcycle)	3.89 (36.43)
Age $\geq$ 45 (bus)	-0.82 (-2.69)
License (car, motorcycle)	1.55 (34.45)

note: t-statistics in parenthesis

Source: Morikawa et al. (2003)

Several past studies on elasticities of transportation demand tend to give different values of elasticities. Oum T.H et al. (1990) identified several factors which may have contributed to this diversity. First, some studies fail to control for presence of intermodal competition. As a result, the own-price elasticity estimates reflect the intensity of intermodal competition. Oum T.H et al. (1990) pointed out that if the prices of competitive modes change in the same direction as a mode's own-price, then the own-price elasticities are underestimated. The difference in the elasticity estimates may be also caused by the failure to recognize the presence of multicollinearity, autoregressive errors and other specification problems. Different functional forms used by those studies are also one of the factors. Oum T.H et al.[9] in another paper has proven that, with the same data set, different functional forms could result in widely different elasticity estimates.

Another factor that may cause different elasticity values is the different definitions of variables used. For example, some studies use real vehicle operating costs while others use the nominal values, and some studies normalize costs by income while others not (Oum et al. 1990). The time period of study also determined the elasticity values. Generally, the long-run elasticity is higher than a short-run elasticity because users have more time to adjust to price change. In addition, data drawn from different countries may show different elasticity estimates.

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[9] Refer Oum T.H (1989) *"Alternative Demand Models and Their Elasticity Estimates"*, **Journal of Transport Economics and Policy**, 23, 163-87.