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"Efficiency - Equity - Clarity"

# **Transit Price Elasticities and Cross-Elasticities**

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17 August 2007



## **Abstract**

This paper summarizes price elasticities and cross elasticities for use in public transit planning. It describes how elasticities are used, and summarizes previous research on transit elasticities. Commonly used transit elasticity values are largely based on studies of short- and medium-run impacts performed decades ago when real incomes were lower and a larger portion of the population was transit dependent. As a result, they tend to be lower than appropriate to model long-run impacts. Analysis based on these elasticity values tends to understate the potential of transit fare reductions and service improvements to reduce problems such as traffic congestion and vehicle pollution, and understate the long-term negative impacts that fare increases and service cuts will have on transit ridership, transit revenue, traffic congestion and pollution emissions.

Originally published as

"Transit Price Elasticities and Cross-Elasticities," *Journal of Public Transportation*, Vol. 7, No. 2, ([www.nctr.usf.edu/jpt/pdf/JPT\\_7-2\\_Litman.pdf](http://www.nctr.usf.edu/jpt/pdf/JPT_7-2_Litman.pdf)), 2004, pp. 37-58.

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## Introduction

Prices affect consumers' purchase decisions. For example, a particular product may seem too expensive at its regular price, but a good value when it is discounted. Similarly, a price increase may motivate consumers to use a product less or shift to another brand.

Such decisions are said to be “marginal,” that is, the decision is at the margin between different alternatives, and can therefore be affected by even a small price change. Although individually such decisions may be quite variable and difficult to predict (a consumer might succumb to a sale one day but ignore the same offer the next), in aggregate they tend to follow a predictable pattern: when prices decline consumption increases, and when prices increase consumption declines, all else being equal. This is called the “law of demand.”

This paper summarizes research on how price changes affect transit ridership. *Price* refers to *users' perceived, marginal cost*, that is, the factors that directly affect consumers' purchase decision. This can include both monetary costs and non-market costs such as travel time and discomfort.

Price sensitivity is measured using *elasticities*, defined as the percentage change in consumption resulting from a one-percent change in price, all else held constant. A high elasticity value indicates that a good is price-sensitive, that is, a relatively small change in price causes a relatively large change in consumption. A low elasticity value means that prices have relatively little effect on consumption. The degree of price sensitivity refers to the absolute elasticity value, that is, regardless of whether it is positive or negative.

For example, if the elasticity of transit ridership with respect to (abbreviated “WRT”) transit fares is  $-0.5$ , this means that each 1.0% increase in transit fares causes a 0.5% reduction in ridership, so a 10% fare increase will cause ridership to decline by about 5%. Similarly, if the elasticity of transit ridership with respect to transit service hours is 1.5, a 10% increase in service hours would cause a 15% increase in ridership.

Economists use several terms to classify the relative magnitude of elasticity values. *Unit elasticity* refers to an elasticity with an absolute value of 1.0, meaning that price changes cause a proportional change in consumption. Elasticity values less than 1.0 in absolute value are called *inelastic*, meaning that prices cause less than proportional changes in consumption. Elasticity values greater than 1.0 in absolute value are called *elastic*, meaning that prices cause more than proportional changes in consumption. For example, both a 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.

*Cross-elasticities* refer to the percentage change in the consumption of a good resulting from a price change in another, related good. For example, automobile travel is complementary to vehicle parking and a substitute for transit travel, so an increase in the price of driving tends to reduce demand for parking and increase demand for transit.

To help analyze cross-elasticities it is useful to estimate *mode substitution* factors, such as the change in automobile trips resulting from a change in transit trips. These factors vary depending on circumstances. For example, when bus ridership increases due to reduced fares, typically 10-50% of the added trips will substitute for an automobile trip. Other trips will shift from nonmotorized modes, ridesharing (which consists of vehicle trips that will be made anyway), or be induced travel (including chauffeured automobile travel, in which a driver makes a special trip to carry a passenger). Conversely, when a disincentive such as parking fees or road tolls causes automobile trips to decline, generally 20-60% shift to transit, depending on conditions. Pratt (1999) provides information on the mode shifts that result from various incentives, such as transit service improvements and parking pricing.

Special care is required when calculating the impacts of large price changes, or when predicting the effects of multiple changes such as an increase in fares and a reduction in service, because each subsequent change impacts a different base. For example, if prices increase 10% on a good with a  $-0.5$  elasticity, the first one-percent of price change reduces consumption by 0.5%, to 99.5% of its original amount. The second one-percent price change reduces this 99.5% by another 99.5%, to 99.0%. The third one-percent of price change reduces this 99.0% by another 99.5% to 98.5%, and so on for each one-percent change. In total a 10% price increase reduces consumption 4.9%, not a full 5% that would be calculated by simply multiplying  $-0.5 \times 10$ . This becomes significant when evaluating the impacts of price changes greater than 50%.

Price elasticities have many applications in transportation planning. They can be used to predict the ridership and revenue effects of changes in transit fares; they are used in modeling to predict how changes in transit service will affect vehicle traffic volumes and pollution emissions; and they can help evaluate the impacts and benefits of mobility management strategies such as new transit services, road tolls and parking fees.

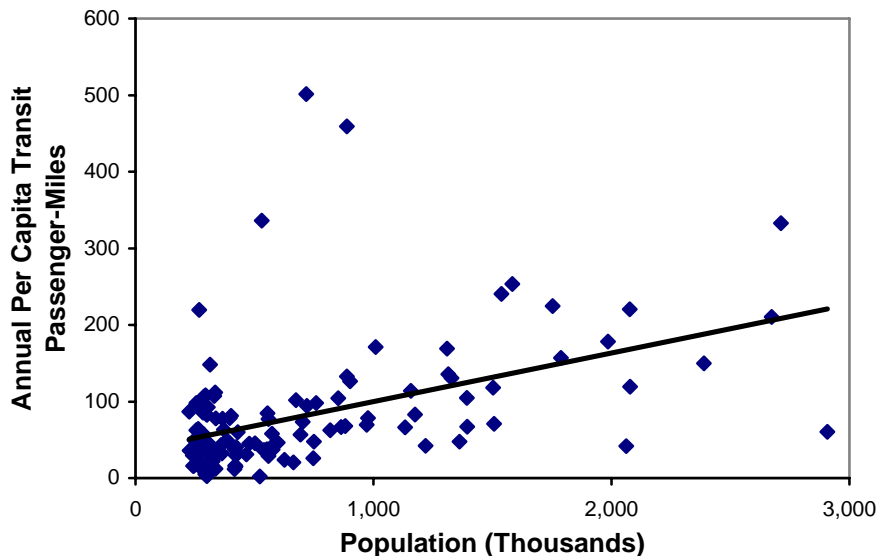
## Factors Affecting Transit Elasticities

Many factors can affect how prices affect consumption decisions. They can vary depending on how elasticities are defined, the type of good or service affected, the category of customer, the quality of substitutes, and other market factors. It is important to consider these factors in elasticity analysis.

Some factors that affect transit elasticities are summarized below.

- *User Type.* Transit dependent riders are generally less price sensitive than *choice* or *discretionary* riders (people who have the option of using an automobile for that trip). Certain demographic groups, including people with low incomes, non-drivers, people with disabilities, high school and college students, and elderly people tend to be more transit dependent. In most communities transit dependent people are a relatively small portion of the total population but a large portion of transit users, while discretionary riders are a potentially large but more price elastic transit market segment.
- *Trip Type.* Non-commute trips tend to be more price sensitive than commute trips. Elasticities for off-peak transit travel are typically 1.5-2 times higher than peak period elasticities, because peak-period travel largely consists of commute trips.
- *Geography.* Large cities tend to have lower price elasticities than suburbs and smaller cities, because they have a greater portion of transit-dependent users. Per capita annual transit ridership tends to increase with city size, as illustrated in Figure 1, due to increased traffic congestion and parking costs, and improved transit service due to economies of scale.

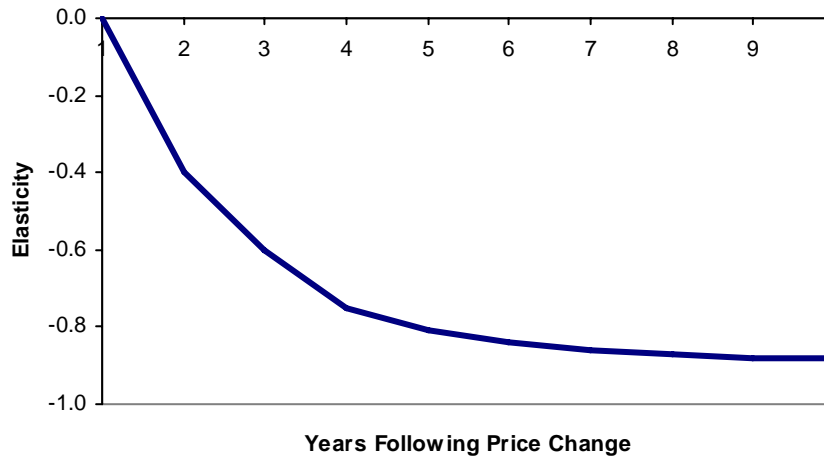
**Figure 1** Transit Ridership Versus City Size (FTA, 2001)



This graph illustrates the relationship between city size and annual per-capita transit travel for U.S. cities between 200,000 and 3,000,000 population. Per capita ridership tends to grow with city size, due to increasing automobile costs and transit service efficiencies.

- *Type of Price Change.* Transit fares, service quality (service speed, frequency, coverage and comfort) and parking pricing tend to have the greatest impact on transit ridership. Elasticities appear to increase somewhat as fare levels increase (i.e., when the starting point of a fare increase is relatively high).
- *Direction of Price Change.* Transportation demand models often apply the same elasticity value to both price increases and reductions, but there is evidence that some changes are non-symmetric. Fare increases tend to cause a greater reduction in ridership than the same size fare reduction will increase ridership. A price increase or transit strike that induces households to purchase an automobile may be somewhat irreversible, since once people become accustomed to driving they often continue.

**Figure 2** Dynamic Elasticity (Dargay and Hanly, 1999)

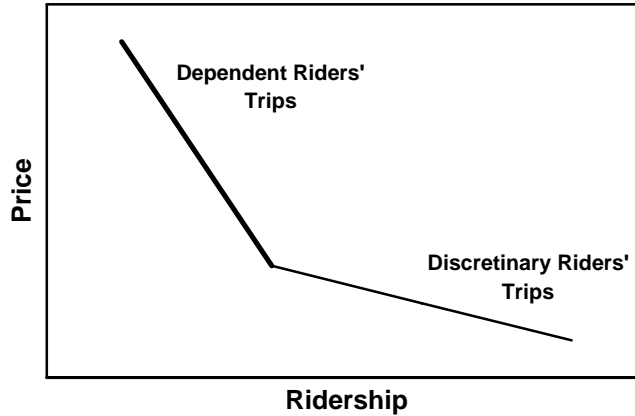


*The absolute magnitude of elasticity values tend to increase over time. Long-run transit elasticities tend to be two or three times as large as short-run elasticities.*

- *Time Period.* Price impacts are often categorized as short-run (less than two years), medium-run (within five years) and long-run (more than five years). Elasticities increase over time, as consumers take price changes into account in longer-term decisions, such as where to live or work, as illustrated in Figure 2. Long-run transit elasticities tend to be two or three times as large as short-run elasticities.
- *Transit Type.* Bus and rail often have different elasticities because they serve different markets, although how they differ depends on specific conditions.

Because there is significant difference in demand between dependent and discretionary riders we can say there is a “kink” in the demand curve (Clements, 1997), as illustrated in Figure 3. As a result, elasticity values depend on what portion of the demand curve is being measured. Price changes may have relatively little impact on ridership for a basic transit system that primarily serves transit dependent users, but if the transit system wants to attract significantly more riders and reduce automobile travel, fares will need to decline and service improve to attract more price sensitive discretionary riders.

**Figure 3 A Kink In the Demand Curve**



*Transit dependent riders tend to be less price sensitive than discretionary riders, so elasticity values tend to decline once their basic demand is satisfied.*

**Summary of Transit Elasticity Studies**

Many studies have been performed on the price elasticity of public transit, and several previous publications have summarized the results of such studies, including Pham and Linsalata (1991); Oum, Waters, and Yong (1992); Goodwin (1992); Luk and Hepburn (1993); Pratt (1999); Dargay and Hanly (1999), TRACE (1999), Booz Allen Hamilton (2003) and TRL (2004). Significant results from this research are summarized below.

**General Transit Fare Elasticity Values**

A frequently-used rule-of-thumb, known as the *Simpson – Curtin* rule, is that each 3% fare increase reduces ridership by 1%. Like most rules-of-thumb, this can be useful for rough analysis, but it is too simplistic and outdated for detailed planning and modeling.

Table 1 shows bus fare elasticity values published by the American Public Transportation Association, and widely used for transit planning and modeling in North America. This was based on a study of the short-run (less than two years) effects of fare changes in 52 U.S. transit systems during the late 1980s. Because they reflect short-run impacts and are based on studies performed when a larger portion of the population was transit-dependent, these values probably understate the long-run impacts of current price changes.

**Table 1 Bus Fare Elasticities (Pham and Linsalata, 1991)**

	<b>Large Cities (More than One Million Population)</b>	<b>Smaller Cities (Less than One Million Population)</b>
Average for All Hours	-0.36	-0.43
Peak Hour	-0.18	-0.27
Off-Peak	-0.39	-0.46
Off-peak Average	-0.42	
Peak Hour Average	-0.23	

*This table summarizes U.S. transit fare elasticities published by the American Public Transportation Association.*

After a detailed review of international studies, Goodwin (1992) produced the average elasticity values summarized in Table 2. He noted that price impacts tend to increase over time as consumers have more options (related to increases in real incomes, automobile ownership, and now telecommunications that can substitute for physical travel). Nelson, et al (2006) found similar values in their analysis of Washington DC transit demand. Nijkamp and Pepping (1998) found elasticities in the  $-0.4$  to  $-0.6$  range in a meta-analysis of European transit elasticity studies.

**Table 2**      **Transportation Elasticities** (Goodwin, 1992)

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

*This table summarizes international transportation elasticities. Note that long-run effects (more than one year) are typically about twice short run effects. (“WRT” = With Respect To).*

Dargay and Hanly (1999) studied the effects of UK transit bus fare changes over several years to derive the elasticity values summarized in Table 3. They used a dynamic econometric model (separate short- and long-run effects) of per capita bus patronage, per capita income, bus fares and service levels. 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 to falling fares ( $-0.3$  in the short run and  $-0.6$  in the long run), and that demand tends to be more price sensitive at higher fare levels. They found that 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 transit fares is 0.4, while the elasticity of *car use* with respect to transit fares is 0.3.

**Table 3**      **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 major UK study.*

Another study compared transit elasticities in the UK and France between 1975 and 1995 (Dargay, et al, 2002). It indicates that transit ridership declines with income (although not in Paris, where wealthy people are more likely to ride transit than in most other regions) and with higher fares, and increases with increased transit service kilometers. These researchers found that transit elasticities have increased during this period. Table 4 summarizes their findings.

**Table 4 Transit Elasticities** (Dargay, et al, 2002, table 4)

	England		France	
	Log-Log	Semi-Log	Log-Log	Semi-Log
<b>Income</b>				
Short Run	-0.67	-0.69	-0.05	-0.04
Long Run	-0.90	-0.95	-0.09	-0.07
<b>Fare</b>				
Short Run	-0.51	-0.54	-0.32	-0.30
Long Run	-0.69	-0.75	-0.61	-0.59
<b>Transit VKM</b>				
Short Run	0.57	0.54	0.29	0.29
Long Run	0.77	0.74	0.57	0.57
<b>Annual Fare Elasticity Growth Rate</b>		1.59%		0.66%

*This table shows mean elasticity values based on 1975 to 1995 data.*

With a log-log function elasticity values are the same at all fare levels, whereas with a semi-log function the elasticity value increases with higher fares. Log-Log functions are most common and generally easiest to use. Semi-log elasticity values are based on an exponential function, and can be used for predicting impacts of fares that approach zero, that is, if transit services become free, but are unsuited for very high fare levels, in which case semi-log may result in exaggerated elasticity values. For typical fare changes, between 10% and 30%, log-log and semi-log functions provide similar results, so either can be used.

Table 5 summarizes estimates of transit fare elasticities for different user groups and trips types, illustrating how various factors affect transit price sensitivities. For example, it indicates that car owners have a greater elasticity (-0.41) than people who are transit dependent (-0.10), and work trips are less elastic than shopping trips.

**Table 5 Transit Fare Elasticities** (Gillen, 1994, pp. 136-37)

Factor	Elasticity
Overall transit fares	-0.33 to -0.22
Riders under 16 years old	-0.32
Riders aged 17-64	-0.22
Riders over 64 years old	-0.14
People earning <\$5,000	-0.19
People earning >\$15,000	-0.28
Car owners	-0.41
People without a car	-0.10
Work trips	-0.10 to -0.19
Shopping trips	-0.32 to -0.49
Off-peak trips	-0.11 to -0.84
Peak trips	-0.04 to -0.32
Trips < 1 mile	-0.55
Trips > 3 miles	-0.29

*This table shows transit fare elasticities disaggregated by rider and trip factors, which can be very useful for many types of transit and transport planning.*

Rail and bus elasticities often differ. In major cities, rail transit fare elasticities tend to be relatively low, typically in the -0.18 range, probably because higher-income residents depend on such systems (Pratt, 1999). For example, the Chicago Transportation Authority found that peak bus riders have an elasticity of -0.30, and off-peak riders -0.46, while rail riders have peak and off-peak elasticities of -0.10 and -0.46, respectively. However, fare elasticities may be relatively high on routes where travelers have viable alternatives, such as for suburban rail systems where most riders are discretionary.

Commuter transit pass programs, in which employers subsidize transit passes, are effective at increasing ridership (Commuter Check, Commuter Choice). Deep Discount transit passes can encourage occasional riders to use transit more frequently, and if implemented when fares are increasing, can avoid ridership losses (Oram and Stark, 1996). Many campus UPass programs, which provide free or discounted transit fares to students and staff, have been quite successful, often doubling or tripling the portion of trips made by transit, because college students tend to be relatively price sensitive (Brown, Hess and Shoup, 2001).

Table 6 summarizes travel demand elasticities developed for use in Australia, based on a review of various national and international studies. These standardized values are used for various transport planning applications throughout the country, modified as appropriate to reflect specific conditions.

**Table 6 Australian Travel Demand Elasticities** (Luk & Hepburn, 1993)

<b>Elasticity Type</b>	<b>Short-Run</b>	<b>Long-Run</b>
Bus demand and fare	-0.29	
Rail demand and fare	-0.35	
Mode shift to transit and petrol price	+0.07	
Mode shift to car and rail fare increase	+0.09	
Road freight demand and road/rail cost ratio	-0.39	-0.80
Petrol consumption and petrol price	-0.12	-0.58
Travel level and petrol price	-0.10	

*This table shows elasticity values adopted by the Australian Road Research Board.*

**Service Elasticities**

*Service elasticities* indicate how transit ridership is affected by transit service quality factors such as availability, convenience, speed and comfort, based on transit vehicle mileage, hours, frequency and priority (Kittleston & Associates, 1999; Phillips, Karachepone and Landis, 2001).

Pratt (1999) finds that completely new bus service in a community that previously had no public transit service typically achieves 3 to 5 annual rides per capita, with 0.8 to 1.2 passengers per bus-mile (0.5 to 0.7 passengers per bus-kilometre). The elasticity of transit use to service expansion (e.g., routes into new parts of a community) is typically in the range of 0.6 to 1.0, meaning that each 1% of additional transit vehicle-miles or vehicle-hours increases ridership by 0.6-1.0%, although much lower and higher response rates are

also found (from less than 0.3 to more than 1.0). The elasticity of transit use with respect to transit service frequency (called a *headway elasticity*) averages 0.5, with greater effects where service is infrequent. There is a wide variation in these factors, depending on type of service, demographic and geographic factors. Higher service elasticities often occur with new express transit service, in university towns, and in suburbs with rail transit stations to feed. On the other hand, some service increases result in little additional ridership. It usually takes 1 to 3 years for new routes to reach their full potential ridership.

Portland, Oregon's *Streamline* program includes various transit operational improvements that improved service quality and efficiency on designated Frequent Service routes (Koonce, et al, 2006). Between 1999 and 2005, the number of vehicle-hours allocated to the twelve streamlined routes has increased 16.3% while ridership on those routes has increased 18.2%, while the number of vehicle-hours allocated to non-Frequent Service routes decreased 2.4% and ridership on those routes decreased 0.7% during the same time period. The change in ridership on the non-Frequent Service routes corresponds to an elasticity of 0.30; that is, for every 1% increase or decrease in service hours, ridership increases or decreases by 0.3%. This elasticity is typical for urban systems with routes operating at 30-minute or better headways. In contrast, the elasticity observed for the streamlined routes was 1.11; that is, ridership increased at a faster rate than service was being added. Elasticities this high are normally only seen in suburban systems that operated at 60-minute headways prior to the service increase. This high level of ridership increase on urban routes suggests that other factors were at work beyond the service frequency increase, although it undoubtedly played a large role.

Approximately 35% more bus rapid transit (BRT) service is needed compared with rail service to attract the same peak-period ridership, indicating that rail passengers accept more crowding than bus passengers (Demery and Higgins, 2002).

Voith (1991) found that, as with monetary price elasticities, service elasticities tend to increase over time. He concludes, "The findings suggest that reductions in public transportation subsidies that result in higher fares and lower service quality may produce higher subsidy costs per rider than would be the case with higher total subsidy. Thus, the results from this analysis support the common public perception that raising public transit fares and reducing service simply reduce ridership, requiring further fare increases and service cuts."

Improved marketing, schedule information, easy-to-remember departure times (for example, every hour or half-hour), and more convenient transfers can also increase transit use, particularly in areas where service is less frequent (Turnbull and Pratt, 2003).

### **Multi-Modal Models**

Some researchers have assembled elasticity and cross-elasticity data to create models that predict how various combinations of changes in transit fares, transit service and vehicle operating costs would affect transit ridership and automobile travel. These models can help answer questions concerning the potential role that transit can play in addressing strategic transportation objectives such as congestion and emission reductions. They can help predict the impacts of integrated mobility management programs that include complementary strategies to encourage more efficient transportation patterns, such as combinations of service improvements, fare reductions and parking or road pricing.

The METS (MEtropolitan Transport Simulator, IFS, 2001) is an urban transport demand simulation model available on the Internet (<http://vla.ifs.org.uk/models/mets22.html>). METS was developed in the early 1980s for use by the UK Department of Transport, and updated in 2000. It allows users to predict the changes in transit and automobile travel that would result from changes in transit service quality, frequency, fares and car costs.

Hensher developed a model of cross-elasticities between various forms of transit and car use, illustrated in Table 7. This type of analysis can be used to predict the effects that transit fare changes will have on vehicle traffic, and the effect that road tolls or parking fees will have on transit ridership. Such models tend to be sensitive to specific demographic and geographic conditions and so must be calibrated for each area.

**Table 7 Direct and Cross-Share Elasticities (Hensher, 1997, Table 8)**

	<b>Train</b>	<b>Train</b>	<b>Train</b>	<b>Bus</b>	<b>Bus</b>	<b>Bus</b>	<b>Car</b>
	Single Fare	Ten Fare	Pass	Single Fare	Ten Fare	Pass	
Train, single fare	-0.218	0.001	0.001	0.057	0.005	0.005	0.196
Train, ten fare	0.001	-0.093	0.001	0.001	0.001	0.006	0.092
Train, pass	0.001	0.001	-0.196	0.001	0.012	0.001	0.335
Bus, single fare	0.067	0.001	0.001	-0.357	0.001	0.001	0.116
Bus, ten fare	0.020	0.004	0.002	0.001	-0.160	0.001	0.121
Bus, pass	0.007	0.036	0.001	0.001	0.001	-0.098	0.020
Car	0.053	0.042	0.003	0.066	0.016	0.003	-0.197

*This table indicates how various changes in transit fares and car operating costs affects transit and car travel demand. For example, a 10% increase in single fare train tickets will cause a 2.18 reduction in the sale of those fares, and a 0.57% increase in single fare bus tickets. This is based on a survey of residents of Newcastle, a small Australian city.*

TRACE (1999) provides detailed elasticity and cross elasticity estimates for various types of travel (car-trips, car-kilometers, transit travel, walking/cycling, commuting, business, etc.) and conditions, based on numerous European 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.

It estimates that a 10% rise in fuel prices increases transit ridership 1.6% in the short run and 1.2% over the long run, depending on regional vehicle ownership. This declining

elasticity value is unique to fuel, because fuel price increases cause motorists to purchase more fuel efficient vehicles. Table 8 summarizes elasticities of trips and kilometers with respect to fuel prices in areas with high vehicle ownership (more than 450 vehicles per 1,000 population).

**Table 8 Elasticities WRT Fuel Price (TRACE, 1999, Tables 8 & 9)**

Term/Purpose	Car Driver	Car Passenger	Public Transport	Slow Modes
<b>Trips</b>				
Commuting	-0.11	+0.19	+0.20	+0.18
Business	-0.04	+0.21	+0.24	+0.19
Education	-0.18	+0.00	+0.01	+0.01
Other	-0.25	+0.15	+0.15	+0.14
<i>Total</i>	<i>-0.19</i>	<i>+0.16</i>	<i>+0.13</i>	<i>+0.13</i>
<b>Kilometers</b>				
Commuting	-0.20	+0.20	+0.22	+0.19
Business	-0.22	+0.05	+0.05	+0.04
Education	-0.32	+0.00	+0.00	+0.01
Other	-0.44	+0.15	+0.18	+0.16
<i>Total</i>	<i>-0.29</i>	<i>+0.15</i>	<i>+0.14</i>	<i>+0.13</i>

Slow Modes = Walking and Cycling

WRT = With Respect To

*This table shows the estimated elasticities and cross-elasticities of urban travel in response to a change in fuel price or other vehicle operating costs.*

Parking prices and road tolls tend to have a greater impact on transit ridership than other vehicle costs such as fuel, typically by a factor of 1.5 to 2.0, because they are paid directly on a per-trip basis. Table 9 shows how parking prices affects travel in a relatively automobile-oriented urban region.

**Table 9 Parking Price Elasticities (TRACE, 1999, Tables 32 & 33)**

Term/Purpose	Car Driver	Car Passenger	Public Transport	Slow mode
<b>Trips</b>				
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
<i>Total</i>	<i>-0.16</i>	<i>+0.03</i>	<i>+0.02</i>	<i>+0.03</i>
<b>Kilometres</b>				
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
<i>Total</i>	<i>-0.07</i>	<i>+0.02</i>	<i>+0.01</i>	<i>+0.03</i>

Slow Modes = Walking and Cycling

WRT = With Respect To

*This table indicates how parking prices affect travel by automobile, public transit and slow modes.*

**Table 10 Parking Elasticities** (Hensher and King, 2001, Table 6)

	Preferred CBD	Less Preferred CBD	CBD Fringe
Car Trip, Preferred CBD	-0.541	0.205	0.035
Car Trip, Less Preferred CBD	0.837	-0.015	0.043
Car Trip, CBD Fringe	0.965	0.286	-0.476
<i>Park &amp; Ride</i>	<i>0.363</i>	<i>0.136</i>	<i>0.029</i>
<i>Ride Public Transit</i>	<i>0.291</i>	<i>0.104</i>	<i>0.023</i>
Forego CBD Trip	0.469	0.150	0.029

*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 Transit trips and a 4.69 reduction in total CBD trips.*

Hensher and King (1998) calculate elasticities and cross-elasticities for various forms of transit fares and automobile travel in central Sydney, Australia, as summarized in Table 10. Fearnley and Bekken (2005) summarize elasticity research and calculate the ratio of short- to long-run effects, as summarized in Table 11.

**Table 34 Transit Elasticities** (Fearnley and Bekken, 2005)

	Short-run Elasticity	Long-run Elasticity	Long-Run/Short-Run
Service Level, Local Public Transport	0.43	0.75	1.84
Fare Level, Local Public Transport	-0.44	-0.76	1.92
Fare Level, Train/Metro	-0.61	-0.98	1.59
<i>Average Ratio long-run/short-Run</i>			<i>1.84</i>

Fehr & Peers (2004) develop “Direct Ridership Models” for predicting the effects of various changes on transit ridership, based on regression analysis of various North American transit systems. Table 12 provides examples of their results.

**Table 12 Impacts on Transit Ridership** (Fehr & Peers, 2004)

Given a 100% Increase In	Expect Ridership Increase
Population and employment within ½ mile of transit station.	23%
Population within station catchment.	2%
Number of peak period trains.	48%
Peak-period feeder buses.	29%
Parking spaces.	4%

*This table shows how various transit system changes affect transit ridership.*

Currie and Justin Phung (2007) calculated the aggregate cross-elasticity of US transit demand with respect to fuel price ( $e$ ) to be 0.12, indicating that transit demand increases 1.2% for every 10% gas price increase. US light rail is particularly sensitive to gas prices, with values for ( $e$ ) measured at 0.27 to 0.38. Bus ridership is only slightly sensitive to gas prices ( $e=0.04$ ) and heavy rail is higher (0.17) which is consistent with most international evidence. A longitudinal model suggests some acceleration in transit mode sensitivity.

Haire and Machemehl (2007) found similar results. Analyzing ridership in five U.S. cities they found statistically significant correlation between ridership and fuel prices, suggesting that rising fuel prices increased transit use in historically auto-oriented American cities. They estimate that, on average, a one percent rise in fuel prices increases transit demand approximately 0.24 percent. This relationship translates to an approximate 0.09 percent increase in ridership for each additional cent of fuel price.

## **Conclusions and Recommendations**

An important conclusion of this research is that no single transit elasticity value applies in all situations: various factors affect price sensitivities including type of user and trip, geographic conditions and time period.

Available evidence suggests that the elasticity of transit ridership with respect to fares is usually in the  $-0.2$  to  $-0.5$  range in the short run (first year), and increases to  $-0.6$  to  $-0.9$  over the long run (five to ten years). These are affected by the following factors:

- Transit price elasticities are lower for transit dependent riders than for discretionary (“choice”) riders.
- Elasticities are about twice as high for off-peak and leisure travel as for peak and commute travel.
- Cross-elasticities between transit and automobile travel are relatively low in the short run (0.05), but increase over the long run (probably to 0.3 and perhaps as high as 0.4).
- A relatively large fare reduction is generally needed to attract motorists to transit, since they are discretionary riders. Such travelers may be more responsive to service quality (speed, frequency and comfort), and higher automobile operating costs through road or parking pricing.
- Due to variability and uncertainty it is preferable to use ranges rather than point values for elasticity analysis.

Commonly used transit elasticity values primarily reflect short- and medium-run impacts and are based on studies performed 10-40 years ago, when real incomes were lower and a greater portion of the population was transit dependent. The resulting elasticity values may be appropriate for predicting how a change in transit fares or service will affect next year’s ridership and revenue, but long-run elasticity values are more appropriate for strategic planning. Conventional traffic models that use standard elasticity values based on short-run price effects tend to understate the potential of transit fare reductions and service improvements to reduce problems such as traffic congestion and vehicle pollution. Conversely, these models will understate the long-term negative impacts that fare increases and service cuts can have on transit ridership, transit revenue, traffic congestion and pollution emissions.

In most communities (particularly outside of large cities) transit dependent people are a relatively small portion of the total population, while discretionary riders (people who

have the option of driving) are a potentially large but more price sensitive market segment. As a result, increasing transit ridership requires pricing and incentives that attract travelers out of their car. Combinations of fare reductions and discounted passes, higher vehicle user fees (such as priced parking or road tolls), improved transit service, and better transit marketing can be particularly effective at increasing transit ridership and reducing automobile use (VTPI, 2002).

Transit planners generally assume that transit is price inelastic (elasticity values are less than 1.0), so fare increases and service reductions increase net revenue. This tends to be true in the short-run (less than two years), but long-run elasticities approach 1.0, so financial gains decline over time.

Not all of the increased transit ridership that results from fare reductions and service improvements represents a reduction in automobile travel. Much of this additional ridership may substitute for walking, cycling or rideshare trips, or consist of absolute increases in total personal mobility. In typical situations, a quarter to half of increased transit ridership represents a reduction in automobile travel, but this varies considerably depending on specific conditions.

Table 13 summarizes recommended generic values based on this research. These values reflect the results of numerous studies, presented in a format to facilitate their application in typical transport planning situations. High and low values are presented to allow sensitivity analysis, or a midpoint value can be used. Actual elasticities vary depending on circumstances, so additional review and research is recommended to improve and validate these values, and modify them to specific situations.

**Table 13 Recommended Transit Elasticity Values**

	<b>Market Segment</b>	<b>Short Term</b>	<b>Long Term</b>
Transit ridership WRT transit fares	Overall	-0.2 to -0.5	-0.6 to -0.9
Transit ridership WRT transit fares	Peak	-0.15 to -0.3	-0.4 to -0.6
Transit ridership WRT transit fares	Off-peak	-0.3 to -0.6	-0.8 to -1.0
Transit ridership WRT transit fares	Suburban Commuters	-0.3 to -0.6	-0.8 to -1.0
Transit ridership WRT transit service	Overall	0.50 to 0.7	0.7 to 1.1
Transit ridership WRT auto operating costs	Overall	0.05 to 0.15	0.2 to 0.4
Automobile travel WRT transit costs	Overall	0.03 to 0.1	0.15 to 0.3

*This table summarizes recommended values resulting from this study. These values should be modified as appropriate to reflect specific conditions. (WRT = With Respect To)*

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## **Acknowledgements**

Much of the research for this paper was performed with the support of TransLink, the Vancouver regional transportation agency. The author gratefully acknowledges assistance from Professor Yossi Berechman, Dr. Joyce Dargay, Professor Phil Goodwin, Dr. John Holtzclaw, Professor Robert Noland, Richard Pratt, Professor John Pucher, Clive Rock and Professor Bill Waters. Any errors are, of course my own.