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AUSTRALASIAN TRAVEL DEMAND ELASTICITIES - AN UPDATE OF THE EVIDENCE

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ABSTRACT

The last substantial published review of evidence on travel demand elasticities in Australia was published in 1993 [1] and most of the studies it covers date from the 1980s. Since that time a considerable amount of further evidence has become available.

This paper presents an update and re-examination of travel demand elasticity evidence for Australia and also brings together evidence from New Zealand. The emphasis is on urban public transport direct elasticities (fares and service levels) and cross-elasticities with respect to car travel times and usage costs. Particular attention is paid to segmentation of elasticity estimates by key variables, including long run and short run differences, trip length differences, and time of day/trip purpose differences.

The paper reports on parts of a wider review of travel demand elasticity evidence undertaken by Booz Allen Hamilton for Transfund New Zealand.

[1] ***Luk J and Hepburn S (1993). 'New Review of Australian Travel Demand Elasticities'. Research Report ARR No. 249, Australian Road Research Board.***

1. INTRODUCTION

Elasticity is a measure of the sensitivity of one variable to changes in another variable. Travel demand elasticities, which are the topic of this paper, are measures of the sensitivity of travel demand to changes in variables such as price and service level. The elasticity is calculated as the ratio of the proportionate change in demand to the proportionate change in the independent factor (price, etc).

While demand elasticities may be regarded as rather crude measures of aggregate market response, they are in practice an extremely valuable tool in transport policy analysis, to supplement or often to replace more complex transport models. As noted by Goodwin (1992):

> *"Demand elasticities are, in general, rather crude and approximate measures of aggregate responses in a market. They do, however, have the great attractions of being empirically estimable, reasonably easily understood, tested by experience, and directly usable for policy assessment."*

In the authors' experience in assessing the likely impacts of urban transport policy, pricing and service initiatives, an elasticity-based assessment is often the only approach appropriate; and, where more formal models (eg. multi-modal urban transport models) are available they should be treated with particular scepticism if they give results inconsistent with those from an elasticity approach.

This paper reports the findings from a research project undertaken by Booz Allen Hamilton for Transfund NZ, to review evidence available in Australasia and internationally on public transport demand elasticities and to develop a set of recommended elasticities for application for urban transport policy analysis in New Zealand.

The primary focus of the project was on elasticities impacting on the demand for **public transport**, principally in an urban context. Public transport demand may be affected by policy measures of two types:

- Measures applied directly to the **public transport** system ('carrot' measures), eg. change in fares, service levels, bus travel times. Relevant elasticities are the 'direct' elasticities of public transport demand with respect to changes in the public transport system variable.

- Measures applied directly to **private transport (car)** travel ('stick' measures), eg. changes in fuel prices, car parking charges. Such measures have a direct effect on car travel, measured by a 'direct' elasticity of car travel demand with respect to changes in the car variable; and hence an indirect (cross-modal) effect on public transport travel, measured by a 'cross-elasticity' of public transport demand with respect to changes in the car variable.

The project was concerned with direct elasticities for the 'carrot' measures, and with both direct and cross-elasticities for the 'stick' measures. Table 1 presents a summary of its scope in this regard.

The project involved:

- An extensive review of the international elasticity literature from the last 20-30 years, relating to each variable in Table 1.
- A particular focus in this review on NZ and Australian literature (which is the main focus of this paper).
- Summary and appraisal of the literature review findings and consideration of their transferability to the NZ situation.
- Development therefrom of a set of elasticity values and guidelines applicable for urban transport policy assessment in the NZ context.

TABLE 1: SCOPE OF ANALYSIS

Variable	Impacts on: [1]	
	Public Transport Demand	**Private Transport Demand**
Public Transport Variables		
A. Fares	★ (27/12)	
B. Service Levels	★ (11/10)	
C. In-vehicle Time	★ (8/-)	
D. Reliability	★ (-/-)	
E. Public Transport Generalised Costs	★ (-/-)	
Private Transport Variables		
F. Fuel Prices	★ (4/2)	★ (6/-)
G. Other Vehicle Operating Costs	★ (3/1)	★ (4/-)
H. Toll Charges	★ (-/-)	★ (5/-)
I. Parking Charges	★ (3/-)	★ (6/-)
J. In-vehicle Time	★ (5/-)	★ (5/-)
K. Car Generalised Costs	★ (-/-)	★ (-/-)

Notes: [1] Numbers in brackets relate to number of separate Australasian studies identified for elasticity values (Australia / NZ). Often individual studies include several values.

2. OVERVIEW OF THE LITERATURE

2.1 INTERNATIONAL LITERATURE

The study of urban transport demand elasticities internationally appears to have started in earnest in the 1970s, and by now empirical estimates have been derived from some thousands of individual studies. Of particular interest for this project are some key summary reviews, which have drawn together results from numerous individual studies and attempted to draw conclusions useful for policy purposes.

Internationally, these key review studies may be grouped into three 'waves', each about a decade apart:

Early 1980s

- The UK Transport and Road Research Laboratory coordinated an 'International Collaborative Study of the Factors Affecting Public Transport Patronage'. Participants were primarily 'western' countries, from Europe, North America and including Australia and New Zealand. The study report (often known as the 'Black Book') was published in 1980 (TRRL, 1980): it has served as a 'bible' on the subject for some 20 years.

- Over almost the same time period, the US Department of Transportation prepared a document of broadly similar scope, but focussing almost entirely on USA empirical evidence. This was published in 1981 (Barton–Aschman Associates, 1981).

Early 1990s

In 1992, two major elasticity review articles were published, through the Journal of Transport Economics and Policy:

- Article by Dr Phil Goodwin, drawing primarily on UK/European literature, including many unpublished sources, and focussing on urban transport (car and public transport) elasticities (Goodwin, 1992). This article particularly addressed short-run and long-run elasticity effects.

- Article by Oum et al (1992), drawing primarily on North American sources, principally from academic journals, and with a wide coverage across both passenger (including inter-city and air travel) and freight transport.

Early 2000s

- Currently, a comprehensive update of the 1980 'Demand for Public Transport' (DFPT) report is being undertaken, again coordinated by the UK Transport Research Laboratory. This update has a primarily-UK focus, without substantial involvement from other 'western' countries. However, our NZ research has liaised with the DFPT project team and had access to its draft papers.

- As in the early 1980s, the USA evidence is being progressively updated more-or-less in parallel with the UK work (RH Pratt et al for TCRP, 2000).

2.2 AUSTRALASIAN LITERATURE

In **Australia**, a number of individual studies undertaken in the 1970s and 1980s derived estimates of urban transport demand elasticities. These were brought together in a major review study in 1993 for the Australian Road Research Board (Luk and Hepburn, 1993). This review aimed to derive elasticity values appropriate for the assessment of price-based travel demand management (TDM) initiatives in Australian cities. It summarised Australian evidence on urban transport price elasticities and compared these with Goodwin's (1992) findings largely based on UK/European data. In total, it identified 15 separate studies (mostly from the 1970s and 1980s) that had derived elasticity values relevant to the variables covered in this project (Table 1): 10 of these related to fares elasticities, the other 5 to fuel price direct and cross-elasticities.

In comparing the Australian evidence with the average figures found by Goodwin, Luk & Hepburn commented that fuel price elasticities in Australia appeared to be less than Goodwin's averages; but that public transport fare elasticities appeared to be similar. However, while plausible, these conclusions should probably be regarded as indicative only, given the small number of Australian studies on which they were based.
A number of other review studies of Australian elasticity evidence have been undertaken over the last 10 years, some of which are widely available (eg. Industry Commission, 1994), but many of which comprise unpublished reports, often by consultants. In addition, the Australian Bureau of Transport and Regional Economics has compiled an extensive database of international elasticity estimates for all transport modes, both passenger and freight (BTRE 1999). However, the Luk & Hepburn review remains the most widely quoted source on Australian evidence.

In **New Zealand**, a review broadly comparable to that by Luk & Hepburn for Australia was carried out in 1990. This covered NZ sources of evidence on both direct and cross-elasticities for urban public transport (Travers Morgan 1990, Wallis & Yates 1990). It identified 8 separate NZ studies that had previously derived relevant elasticity values; and also undertook regression analyses on annual patronage in major centres to derive additional values.

2.3 SCOPE OF PROJECT LITERATURE REVIEW

As noted earlier, the project centred round an extensive literature review of urban transport demand elasticity estimates for each of the variables listed in Table 1. Key features of this review were:

- Covered evidence available internationally, but had a particular focus on capturing evidence from NZ and Australia.
- Covered evidence from last 20 – 30 years.
- Made use of review articles wherever possible (for reasons of efficiency), but also covered original source articles where available.
- Closely coordinated with current UK (DFPT) work, so as to ensure access to more recent UK/European evidence.

The full literature review is presented in the study report (BAH, 2003). For each variable of interest, Table 1 includes figures on how many separate studies providing aggregate elasticity estimates were identified for Australia and for New Zealand (note that an individual study may provide several elasticity estimates). It is notable that:

- It has been possible to identify many more studies (for Australia) than those reviewed by Luk & Hepburn (1993). To a large degree this is accounted for by new studies undertaken over the last 10 years, although many of these have not been made widely available.
- Over half the total studies (112) related to values for public transport fares (39) and service levels (21).
- For most other variables, there are very few (maximum 8) relevant studies, particularly for New Zealand. At a more disaggregate level, there are even fewer relevant Australasian studies.

Given the 'patchiness' of the Australasian evidence, in developing conclusions and recommendations on appropriate elasticity values for New Zealand, our approach has been to supplement the available Australasian values with values from international evidence, but giving relatively greater weight to the Australasian values (where these have been derived in a rigorous manner). It is notable that, for those variables (fares, service levels) for which considerable Australasian evidence exists, this evidence appears to be fully consistent with the weight of the international evidence. This gives some confidence that international values are generally reasonably transferable to the NZ/Australian situation.

3. ELASTICITY CONCEPTS, MEASURES AND ISSUES

3.1 ELASTICITY MEASURES

Although the elasticity concept is reasonably straight-forward, at least three different measures of elasticity are commonly calculated and reported:

- Point elasticity
- Arc elasticity
- Shrinkage ratio.

The definitions of and differences between these three measures are discussed in detail in the study report. The differences between these measures become important in cases of relatively large changes (eg. 30% or more) in the independent variables. There is often inconsistency in the literature over elasticity terminology and many studies do not make clear which measures are calculated. There is a growing use of arc elasticities as the preferred approach with quasi-experimental data, and this review has used these wherever available.

3.2 DATA SOURCES AND METHODS OF ESTIMATION

Two main categories of data may be used as the basis for estimating demand elasticities:

(i) **Revealed preference (RP)** data – data on observed behaviour revealing choices that have actually been made by travellers. There are four main types of RP data, each with related methods of data analysis (further details given in the study report):
   - Time series data
   - Cross-sectional data
   - Panel data
   - 'Before and After' data.

(ii) **Stated preference (SP)** data – data based on the stated behavioural intentions of survey respondents when offered a hypothetical set of travel alternatives by the researcher.

Each type of data source and method of estimation has both advantages and disadvantages, and experience also shows that the choice of methodology influences the elasticity estimates themselves. In general, it is found that RP before/after and time series analyses tend to produce the lowest elasticity value; RP cross-sectional models produce higher values; while SP studies tend to produce the highest values (given the tendency of stated responses to over-estimate behavioural changes).

Given the problems in interpreting elasticity values derived from SP studies, where possible the review focussed on RP-based elasticity values.

3.3 FACTORS INFLUENCING ELASTICITY VALUES

No single elasticity value exists that can be applied uniformly in all situations, even within a given city, for any of the variables of interest. Elasticity values are influenced by the following factors:

- Passenger characteristics, eg. price sensitivity (pensioners or full-time workers), age, gender etc
- Trip characteristics, eg. trip purpose, trip length
- Service and city characteristics, eg. mode, degree of competition, availability of alternatives
- Initial level of variable, in particular its importance in relation to total trip ‘costs’
- Magnitude and direction of change in variable, eg. increases or decreases in price, large or small changes
- Time scale over which effects are estimated.

In relation to this last point, research over the last 10 years or so has highlighted that responses to price and service changes are far from ‘instantaneous’, but generally occur progressively over an extended time period. The weight of international evidence indicates that, for most variables, elasticities over the longer term are 1.5 to 3.0 times greater than the short-term responses (within the first 6-12 months). Thus the time scale being considered is of substantial importance both in reviewing elasticities derived in other studies and in applying elasticities for particular purposes: both short-run and long-run effects are likely to be of interest to analysts and policy makers.

In the review, wherever possible we categorised elasticity values into one of three time bands:

- Short Run (SR) – effects typically within 6-12 months of change
- Medium Run (MR – effects within 2 to 7 years, typically after about 5 years
- Long Run (LR) – effects after 8 years or more, and typically 10 to 12 years.

3.4 DIRECT EFFECTS AND CROSS-MODAL EFFECTS

As summarised in Table 1, the project is concerned with the effects of changes in:

- **public** transport system variables on **public** transport demand
- **private** transport system variables on **private** transport demand
- **private** transport system variables on **public** transport demand.

The first two of these effects involve the same mode on both the supply side and the demand side. They may be represented through **direct** (own mode) **elasticities.**

The third effect involves cross-modal impacts. These may be represented through a **cross-elasticity** measure, or through a direct elasticity measure and a **‘diversion**

rate'. In this case, the cross-elasticity is the ratio of the % change in public transport demand to the % change in the private transport variable; while the 'diversion rate' is simply the proportion of deterred private transport trips that switch to public transport. It may be shown mathematically that the cross-elasticity is proportional to the product of the direct elasticity, the diversion rate and the relative (private: public) mode shares.

There is a wealth of experiential evidence that both direct elasticities and diversion rates are relatively stable and hence transferable between situations; whereas modal shares, and hence cross-elasticities, may vary considerably. Thus, in reviewing cross-modal effects we have wherever possible focussed on data on diversion rates in preference to cross-elasticities. Unfortunately the data on cross-elasticities is rather sparse, and that on diversion rates even more so.

3.5 DEFINITION OF THE RELEVANT MARKET

In interpreting and applying elasticity estimates, a clear understanding is needed of the scope of the market in which the change in demand is being assessed. For example, if the service level on a bus route is improved, the extra passengers attracted may switch from:

- other (parallel) bus routes
- other public transport (non-bus) modes
- private transport modes (car, walking, cycling)
- travel to other destinations
- generation of entirely new trips.

Elasticity values will differ according to which of these responses they reflect, for example:

- If services (or fares) are changed on a single bus route, the demand response on that route is likely to be greater than that for the bus system as a whole, because of switching from parallel routes.

- If services (or fares) are changed on one public transport mode (eg. bus), then there is likely to be a greater response on that mode (the 'own mode' elasticity) than if services/fares are changed similarly on other public transport modes ('conditional' elasticity).

- SP-based models typically estimate 'mode-switching' elasticities, for a fixed market; whereas RP-based models estimate total market elasticities, allowing for trip generation/suppression: the SP estimates will therefore typically under-estimate total market elasticities (but this factor may offset the over-estimate of responses commonly found in SP surveys – refer Section 3.2).

3.6 THE 'GENERALISED COST' APPROACH

As noted earlier, elasticity values will typically vary with the base level of the variable being considered relative to the total 'cost' of the trip. Consistent with this, instead of estimating separate elasticities for each travel time and cost component, an alternative approach is to apply the concept of 'generalised cost' (GC) (or 'generalised time' (GT)). GC is a measure composed of the monetary cost of a trip (such as public transport fare) plus other elements of journey time or disutility expressed in monetary terms - such as access and egress time, wait time, interchange and in-vehicle time. The approach assumes that the time for each component can be multiplied by an appropriate unit value of time to give an equivalent cost. The cost components can then be added together, with the fare, to give a total GC for the trip. It is then assumed that the level of demand can be expressed as a function of GC rather than in terms of the individual cost components. GT is the equivalent concept expressed in time (usually in minutes of in-vehicle time).

The GC for public transport is typically expressed as follows:

$$g = f + \alpha_1 t_1 + \alpha_2 t_2 + \alpha_3 t_3$$

where

g = GC per trip
f = fare per trip
t_1, t_2, t_3 = time components (eg. walking, waiting, in-vehicle)
$\alpha_1, \alpha_2, \alpha_3$ = corresponding unit values of time.

The responsiveness of the demand for travel to these variables can be estimated by applying an overall GC elasticity, rather than the individual elasticities with respect to fares, in-vehicle time etc.

This GC approach is often preferable as it gives more consistent results over a range of situations. The empirical evidence is that GC elasticities appear to be sensibly constant (for a given market) over a wide range of journeys with different component costs and elasticities; whereas individual component elasticities tend to vary according to the proportionate contribution of the component to the total generalised cost.

There is a simple relationship between each GC component and its corresponding elasticity: the component elasticities are proportional to the contribution of that component to GC. This is represented mathematically as:

$$e_g/g = e_f/f = e_1/\alpha_1 t_1 = e_2/\alpha_2 t_2, \text{ etc.}$$

Despite the convenience of using the GC approach for elasticity applications, limited direct empirical evidence is available on GC elasticities. Our literature review reports on the evidence that we have been able to identify.

4. PUBLIC TRANSPORT DIRECT EFFECTS – KEY FINDINGS AND RECOMMENDATIONS

4.1 SUMMARY OF FINDINGS

4.1.1 Aggregate Elasticities

Table 2 summarises the range of **short-run** aggregate direct elasticity estimates obtained from the literature review in relation to fares, service levels and in-vehicle time:

- Of the three variables covered in the table, the best evidence (quality and quantity) relates to fares, the next best to service levels, and the least/worst to in-vehicle time.

- Much of the short-run service level elasticity evidence is derived from time series data. This may tend to over-estimate elasticity values due to cause and effect correlations and should be treated with particular caution.

- It is unclear from the evidence whether the elasticities for rail-based services are systematically different from those for bus-based services, or whether the apparent differences are instead a function of the characteristics of the trips made on each mode (eg. rail trips tend to be longer than bus trips and hence a higher in-vehicle time elasticity might be expected). While a common perception would be that rail is more attractive than bus as an alternative to the car, and therefore rail elasticities might be higher (particularly for service levels and in-vehicle time), there is no clear evidence that this is the case.

Table 2 focuses on short-run elasticities. For the **long-run,** the evidence is generally consistent that elasticities are around twice those for the short run on all three variables – but with a reasonable range of between 1.5 times and 2.5 times the short run values.

Table 2 does not include elasticity values relating to service reliability, as little quantitative research is available on this aspect (despite its importance to users). Our conclusions on the two separate aspects of 'reliability' from the evidence that is available are:

- In the case of 'missed trips', the demand elasticity with respect to the change in vehicle kilometres would be 4-5 times that for a scheduled service adjustment: this gives an effective elasticity in the order of 1.5 to 2.0.

- In the general case of irregular services, the elasticity with respect to the standard deviation of arrival times is estimated at around twice the elasticity for in-vehicle time, ie. in the range –0.6 to –1.0.

TABLE 2: SUMMARY OF AGGREGATE ELASTICITY VALUES – Short Run

Variable	Bus		Rail	
	Average	Typical Range	Average	Typical Range
Fares	-0.40	-0.20 to -0.60	-0.30	-0.20 to -0.50
Service Levels (1)	0.35	0.20 to 0.50	0.35	0.20 to 0.50
In-vehicle Time	-0.30	-0.10 to -0.50	-0.50	-0.30 to -0.70

Note: (1) For medium-frequency services typical of NZ urban areas (20-30 mins frequencies).

4.1.2. Disaggregate Elasticities

Table 3 summarises the evidence on the variation of the three key elasticities across a range of trip characteristics:

- As noted above, the most/best evidence relates to fares elasticities, the least/worst relates to in-vehicle time.

- There are strong systematic variations in elasticities between trip purposes and time periods (the two factors being strongly correlated), for all three variables. Weekday off-peak elasticities are around twice peak period elasticities; and weekend elasticities are generally higher than weekday off-peak values.

- Elasticities vary in a complex way with trip distance: this can be explained in part by the availability of substitutes (high elasticities for short trips given the alternative of walking) and in part by the importance of the variable measure in the total trip generalised cost.

4 Elasticities appear to vary systematically with city size, although the fare effect and the service level effect appear to be opposite (this is an aspect with rather limited data).

4 Both fare elasticity and service elasticity appear to vary strongly, and more-or-less linearly, with the magnitude of the base fare or headway. This is particularly important in regard to headways (frequencies): a typical service elasticity would be 0.1 to 0.2 at high frequencies (better than every 10 minutes) increasing to around 0.5 to 0.6 or more at lower frequencies (in the order of hourly or longer). These variations are broadly consistent with a constant generalised cost elasticity formulation (see below).

TABLE 3: SUMMARY OF DISAGGREGATE ELASTICITY EVIDENCE

Aspect	Fares	Service Levels [1]	In-vehicle Time
Time horizon	Long run typically double (range 1.5 to 3.0) short run.	Long run typically about double short run.	Very limited evidence: indicates long run 1.5 to 2.0 times short run.
Trip purpose/time period	Off-peak/non-work typically twice peak/work; weekend most elastic.	Off-peak/non-work typically c. twice peak/work; weekend most elastic (may be partly frequency differences).	Inconclusive re relative elasticities; although most evidence is that off-peak is more elastic than peak.
Trip distance	Highest at very short distances (walk alternative); lowest at short/medium distances; then some increase and then decrease for longest distances (beyond urban area).	Highest at short distances (walk alternative).	Limited evidence – longest trips more elastic than short/medium distance trips.
City size	Lower in larger cities (over 1 million population) – USA evidence.	Higher in larger cities - EU evidence.	No evidence.
Base level of variable	Elasticities broadly proportional to the base fare level (based on recent UK study – otherwise limited evidence).	Elasticities increase with headways (broadly proportional up to c. 60 mins headway).	No firm evidence – although expect elasticities to increase with proportion of total trip (generalised costs) spent in vehicle.
Magnitude of change	No significant variation in elasticities with magnitude of change (majority of studies).	No evidence.	No evidence.
Direction of change	No significant differences for fare increases and decreases (majority of studies).	No evidence.	No evidence.

4 Most studies show no significant difference in elasticities between fare increases or decreases, and between large or small fare changes. There is very little evidence on any differences according to the direction of change for either service levels or in-vehicle time.

4.2 RECOMMENDATIONS

Two alternative approaches might be recommended in applying elasticity values to assess the impacts of changes in public transport services etc: - the individual elasticity approach, and the 'generalised cost' approach.

4.2.1 Individual Elasticity Approach

This approach would apply separate elasticities to any change in fares, service levels, etc. For this purpose we recommend use of the values given in Tables 2, 3 and the associated commentary. We would note in particular:

- The need to determine whether short-run or long-run values are relevant for the application under consideration, and selection of appropriate values accordingly.
- The need to select service level elasticities appropriate to the base frequencies on the service being considered.

4.2.2 Generalised Cost Approach

As discussed earlier, one useful approach to applying elasticity values that provides consistent results over a wide range of situations is the 'generalised cost' formulation. We see considerable merits in adoption of this approach to assessing the effects of changes in urban public transport demand in response to changes in fares, service levels etc. Based on evidence given in the full project report, we suggest the most appropriate GC average elasticity value is –1.0 in the short run. As appropriate, this average value may be disaggregated by the different dimensions given in Table 3.

5. PRIVATE TRANSPORT DIRECT AND CROSS-MODAL EFFECTS – KEY FINDINGS AND RECOMMENDATIONS

5.1 DIRECT EFFECTS – SUMMARY OF FINDINGS

Table 4 summarises evidence from the literature review on the direct elasticities of private transport (car) demand with respect to the five private transport cost and time variables examined. It provides:

- A summary of evidence on aggregate elasticities (short-run and long-run)
- A summary of any available evidence on disaggregate elasticity values (eg. peak v off-peak)
- Additional notes and comments, including on the availability and quality of relevant evidence.

The quality and quantity of the available evidence varies considerably from variable to variable :

- The variable for which the best evidence is available is **fuel prices**, but even for this there is limited disaggregated evidence (and no evidence for NZ).
- The evidence relating to overall **vehicle operating costs** is not extensive, and in most cases it is unclear precisely what costs are included. We therefore give little weight to this evidence in drawing useful conclusions and recommendations.

- For **in-vehicle time**, the quantity and quality of aggregate evidence is moderate, but with very limited disaggregated evidence (and no evidence for NZ).

- For **parking charges**, the quantity and quality of aggregate evidence is quite good, but mainly relating to mode-choice studies for CBD commuters, and to short-run values. Evidence for other market segments/situation is very limited. There is no evidence for NZ.

- For **toll charges**, relevant evidence (for area-wide tolling schemes) is rather limited, but provides reasonably consistent, short-run aggregate results. Again disaggregated evidence is extremely limited, and there is no evidence for NZ.

In terms of the **aggregate** evidence, Table 5 provides an overview of our 'best-estimate' values that are reasonably reliable:

- Long-run values (where available) are broadly twice short-run values: this is consistent with the public transport results (Section 4).

- The in-vehicle time elasticity is about twice the fuel price elasticity. This is consistent with the expected relative importance of the two variables in total trip (generalised) costs. (A typical fuel price of 10¢/km and average speed of 40km/hr results in fuel costs of $4.00/hour. This is broadly half typical values of travel time savings.)

- The toll charge elasticity (short-run) is on a par with the fuel price elasticity. (This suggests the average level of tolls charged in the studies examined is similar in magnitude to petrol costs for the trips involved.)

TABLE 5: SUMMARY OF AGGREGATE DIRECT ELASTICITY BEST ESTIMATES

Variables	Best-estimate Elasticity	
	Short-run	**Long-run**
Fuel prices	-0.15	-0.25
In-vehicle time	-0.30	-0.60
Parking charges (1)	-0.30	N/A
Toll charges	-0.15	N/A

Notes (1) Relates to CBD commuter travel

The **disaggregate** evidence available (refer Table 4) is surprisingly limited. Perhaps the main conclusion that can be drawn is that cost-related elasticity values for the weekday off-peak are around twice those for the peak, and are even higher at weekends. This is again consistent with the public transport results (Section 4).

TABLE 4: SUMMARY OF DIRECT ELASTICITY EVIDENCE

Variable	Aggregate Evidence	Disaggregate Evidence	Additional Notes
Fuel Prices	4 Average short-run values –0.15 (typical range –0.10 to –0.20) 4 Average long-run values –0.25 (typical range –0.20 to –0.30).	4 Off-peak/non-work values typically twice peak/work values; weekend values higher than weekday. 4 Little evidence on values for price decreases v increases.	4 Extensive international evidence on effects of fuel price changes on fuel consumption, less on effects on traffic levels. No NZ studies. 4 Evidence ambiguous as to whether long-run values exceed short-run values (in long-run, people may purchase more fuel efficient cars etc and thus less need for changes in travel habits).
Vehicle Operating Costs	4 Average short-run values –0.20 (typical range –0.10 to –0.25). 4 Average long-run value –0.30 (typical range –0.20 to –0.40).	4 Off-peak/non-work values typically 1.5 to 2.0 times peak values (rather limited evidence).	4 In general this category includes both fixed and variable costs of motoring (including fuel). But in many cases there is lack of a clear definition of what costs are included in the assessments. 4 Also the relevant literature not very extensive and often does not clarify whether estimates are long or short-run. 4 For these reasons the reliability of estimates is questionable.
In-vehicle Time	4 Average short-run values –0.30 (typical range –0.15 to –0.50). 4 Average long-run values –0.60 (typical range –0.30 to –0.80).	4 Very limited evidence – inconclusive on relative values for peak/work v off-peak/non-work trips.	4 Relevant literature not very extensive, and mostly relates to mode choice or cross-sectional studies. 4 No NZ studies.
Parking Charges	4 Typical values (short-run) are –0.30 (range –0.10 to –0.60), for CBD commuter trips. 4 No clear evidence on long run values. 4 No clear evidence on non-CBD commuter or non-commuter trips (non-commuter trips likely to be relatively elastic, as alternative destinations often available).	4 Limited evidence indicates commuter elasticities lower for suburban destinations than CBD destinations (alternative modes less attractive).	4 Relatively few relevant studies on the effects of area-wide parking pricing policies on car travel demand: most of these relate to CBD commuters and focus on mode choice elasticities. Most relevant studies assumed relating to short-run, although often unclear. 4 No NZ studies. 4 Many studies relate to parking demand at an individual site, so not directly relevant.
Toll Charges	4 Typical values (short-run) are –0.15 (range –0.05 to –0.40). 4 No clear evidence on long-run values (likely to be greater than short-run, as for other variables).	4 Very limited evidence – indicates peak and off-peak values similar.	4 Relatively few studies of area-wide tolling or equivalent (where diversion to alternative routes is not a major effect). Most evidence appears to be short-run (before/after studies). 4 No NZ studies. 4 Expect considerable range of results as initial tolls will be very different in different situations.

5.2 DIRECT EFFECTS – RECOMMENDATIONS

As for the public transport elasticities, two alternative elasticity-based approaches might be used in estimating the impacts of changes in private (car) travel costs on travel demand – the individual elasticity approach and the 'generalised cost' approach.

5.2.1 Individual Elasticity Approach

This approach would apply separate elasticities to any changes in the various time/cost components of the car trip. For this purpose we would recommend use of:

- The best estimate aggregate values given in Table 5 (short-run and long-run).
- The range of aggregate values given in Table 4 for purposes of sensitivity testing.
- The disaggregations given in Table 4 when particular market segments are being considered (to the extent that relevant evidence is available).

5.2.2 Generalised Cost Approach

If the 'generalised cost' approach is to be applied, as discussed earlier (Section 3.6), a set of generalised cost elasticities needs to be derived, making use of evidence on the separate component elasticities. Examining the best estimate component elasticity estimates in Table 5, we note that:

- For a typical car trip, the 'marginal' generalised cost (ie. excluding car purchase, fixed costs and arguably maintenance), comprises essentially fuel and travel time: on this basis, the 'marginal' generalised cost elasticity would be about –0.45 in the short-run, -0.85 in the long-run.
- If an 'average' generalised cost approach were taken (ie. including car purchase, fixed costs, etc) total money costs would be around 4 to 5 times petrol costs. Including time costs this would result in an 'average' generalised cost elasticity of around –0.95 to –1.10 in the short-run, -1.60 to –1.85 in the long run (ie. in each case around double the 'marginal' elasticity).
- For most purposes, the 'marginal' generalised cost elasticity values are probably the more relevant, as these contain the cost elements affected by decisions about individual trips.
- The range of generalised cost elasticity estimates derived from these analyses compares quite well with those drawn directly from other studies (as detailed in the literature review).

Based on the evidence above and these other studies, we would recommend the following set of generalised cost elasticities for use in policy assessments:

- Short-run: -0.6 on marginal costs
  -1.2 on average costs (where appropriate)
- Long run: -1.0 on marginal costs
  -2.0 on average costs (where appropriate).

Where needed, these values may be disaggregated based on the evidence given in Table 4.

5.3 CROSS-MODAL EFFECTS – SUMMARY OF FINDINGS

Table 6 presents our summary of the evidence on the cross effects on public transport demand of changes in the five private transport cost and time variables examined. The table summarises the evidence under two headings:

- Cross-elasticity evidence (ie. the proportionate change in public transport use relative to the proportionate change in the relevant cost or time variable).
- Diversion rate evidence (ie. the proportion of 'deterred' car users that switch to public transport).

The quality and quantity of the evidence available is very limited at an **aggregate** level, particularly in relation to diversion rates. At a **disaggregate** level, the evidence is even more limited:

- The variable for which the best evidence is available is **fuel prices**, but even this is limited and results vary over a wide range.
- As for the direct effects, the evidence relating to **vehicle operating costs** is quite limited, and in most cases it is unclear precisely what costs are included. As before, little weight has been given to this evidence.
- For **in-vehicle time**, there is some cross-elasticity evidence but no diversion rate evidence.
- For **parking charges**, there is very limited evidence, and often a lack of clarity regarding what market segments are covered.
- For **toll charges**, the evidence is again very limited and its relevance to the NZ situation is doubtful.

In terms of the evidence itself, the main conclusions that can be drawn on **cross-elasticities** are as follows:

- A wide range of aggregate values is evident from the literature.
- Typical aggregate cross-elasticity values for cost components (eg. fuel prices, VOC) that might apply in the NZ situation are in the order of 0.1 to 0.3.
- Values tend to be higher in situations with a low public transport mode share (eg. USA), lower with a high mode share (eg. EU countries): NZ/Australia would tend to be towards the middle of this spectrum.
- Evidence on long run versus short run values is inconclusive (it can not necessarily be asserted that long run values would be greater than short run values, as in the case of direct elasticities).
- Peak/work trip cross-elasticities tend to be in the order of twice off-peak/non-work values. (Note that this result is 'opposite' to that for direct public transport elasticities, where peak values are typically half off-peak values).

TABLE 6: SUMMARY OF CROSS-MODAL EFFECTS		
Variable	**Cross-Elasticity Evidence**	**Diversion Rate Evidence**
Fuel Prices	4 Most aggregate values (SR) in range 0.07 to 0.30, with typical value c. 0.15. 4 Values significantly higher for peak than off-peak: NZ evidence is for peak value 2 to 3 times off-peak. 4 As expected, values tend to be higher where PT has low base mode share (eg. USA), lower where there is a high PT mode share (eg. Europe). 4 Mixed evidence on LR v SR: reasonable grounds for expecting LR response may be lower than SR response, as scope for other adaptive behaviours.	4 Typical c. 30% of people deterred from car use by higher fuel prices switch to PT. 4 Proportion varies significantly by market segment and situation: - Peak trip proportion is twice or more off-peak proportion (eg. London: peak c. 50%, off-peak c. 25%). - Long trip proportion higher than for short trips (where walking/cycling is competitive alternative). - Higher proportion where quality of PT alternative is higher (eg. CBD trips v suburban trips).
Vehicle Operating Costs	4 Wide range of evidence on aggregate figures: - Aust/NZ: most values in the order of 0.1 - EU: very wide range of estimates (0.03 to 0.8) but with typical figures around 0.3 to 0.4. - USA: few estimates, but appear higher than elsewhere (around 0.8). 4 No clear evidence on LR v SR values 4 Limited evidence indicates peak values in the order of twice off-peak. 4 Mixed evidence on rail v bus values.	4 No direct evidence available (would expect similar results as for fuel prices).
In-vehicle Time	4 Most aggregate values in range 0.07 to 0.40, with typical value around 0.15 to 0.20. 4 Very limited evidence on LR v SR. 4 Limited evidence indicates peak/work values around twice off-peak/non-work values.	4 No direct evidence available. 4 Prima facie, could expect lower diversion rates than for fuel prices (time-sensitive people less likely to switch to PT than cost-sensitive people).
Parking Charges	4 Very limited evidence (none for NZ). 4 Elasticity estimates range from 0.02 to 0.30, but it is often unclear to what market segments they apply (eg. CBD v non-CBD, work v non-work). 4 No evidence on LR v SR, or other segmentation differences.	4 Very limited evidence (none for NZ). 4 Indications are for very high diversion rates for CBD work trips, lower for other purposes and destinations.
Toll Charges	4 Very limited evidence (none for NZ), with values identified in the range 0.17 to 0.80. 4 Best evidence relates to the Singapore Area Licensing Scheme, but dubious whether this is transferable to NZ situation.	4 Very limited evidence (none for NZ). 4 Most relevant evidence (Milan) found that c. 40% of deterred car users switched to PT in response to peak period charging system.

In terms of **diversion rates**, the main conclusions are:

4 For cost variables (eg fuel prices), the typical overall diversion rate is around 30%.

4 Where cost impacts focus differentially on travellers to areas with a good public transport service (eg. CBDs), diversion rates are higher than this overall figure.

- Diversion rates for peak period/work trips are around twice or more those for off-peak/non-work trips.

- Diversion rates for long trips are substantially higher than for short trips (where walking or cycling are competitive alternatives).

- No evidence has been identified on differences in diversion rates (or cross-elasticities) between drivers and passengers.

5.4 CROSS-MODAL EFFECTS – RECOMMENDATIONS

As discussed earlier, we recommend the use of diversion rates rather than cross-elasticity values as providing a firmer base for policy analyses (ie. not sensitive to the base mode shares in each particular situation). Table 7 summarises our recommendations in relation to diversion rates from car to public transport in response to changes in car travel cost or time components.

The following comments may assist in interpretation of these recommendations:

- Diversion rates (proportions) are sensitive to two main factors. The first of these is the 'competitiveness' of the public transport service offered relative to car travel: much higher diversion rates apply to CBD-oriented trips than to typical suburban trips.

- The second factor is trip purpose: work trips typically have diversion rates twice those for non-work trips. (In practice, the trip purpose/time period effect and the public transport service effect are difficult to separate).

- Diversion rates for time components are assumed to be lower than for cost components (although there is insufficient evidence on this point).

- Long run and short run diversion rates are assumed similar (although again the evidence is inconclusive).

- Diversion rates are lower than average for shorter trips (where walking and cycling are competitive modes).

TABLE 7: SUMMARY OF DIVERSION RATE RECOMMENDATIONS

Variable	Average Diversion Rate Recommendation	Estimates by Market Segment
Fuel Price/Vehicle Operating Costs	30%	- Long v short run: inconclusive, assume equal. - Time period/purpose: peak/work proportion approx twice off-peak/non-work proportion. - PT service quality: higher proportions where high level/quality of PT service. - Trip length: lower for short trips.
Toll Charges	c. 40%	- Proportions depend on nature of scheme (all day v peak only etc) and location (primarily CBD trips, all trips etc). - For area-wide/all-day scheme, would expect same diversion rates as for fuel prices/VOC.
Parking Charges	Regional CBD, work trips: 75% Regional CBD, non-work trips and suburban CBD, work trips: 50% Other: not defined	
In-vehicle Time	20%	- As for fuel prices/VOC.

6. CONCLUSIONS

This paper has reported on a study to review the New Zealand, Australian and international evidence on urban travel demand elasticities and to develop elasticity values appropriate for urban transport policy assessment in New Zealand. The focus was on elasticities of demand for public transport – direct effects resulting from changes in the public transport system (fares, services etc); and cross-modal effects (cross-elasticities or diversion rates) resulting from changes in car travel conditions. Both short-run and long-run values were examined, as both time scales are relevant to policy assessment.

For the direct effects associated with public transport system changes, the study recommended:

- Short-run elasticity values (mean, range), by bus and rail modes, for fares, service frequencies and in-vehicle time

- Factors to derive long-run values from short-run values

- A 'generalised cost' methodology and values, for use where appropriate

- Indicative variations in values according to key disaggregation factors (eg. trip purpose/time period, trip distance).

For the cross-modal effects associated with car travel changes, the study recommended:

- Short-run and long-run direct elasticity estimates with respect to fuel prices, toll charges, CBD parking charges and in-vehicle time

- Cross-modal 'diversion rates' with respect to fuel prices, toll charges, CBD parking charges and in-vehicle time.

It was found that, while the international literature on urban travel demand elasticities is extensive, the evidence is still quite sparse on many aspects relevant for urban transport policy assessment. This conclusion is very much reinforced if attention is confined to New Zealand and Australian sources.

Specific issues within the scope of the review where better information is particularly required include:

- Variations in elasticities over time from the initial change – short v medium v long-run effects (and the pattern of 'ramp up')

- Differences in elasticities for (both direct and cross-modal) between rail-based and bus-based modes

- Difference in elasticities according to the 'base' level of the variable and according to the magnitude of the change

- Cross-modal 'diversion rates'

- Transferability of elasticity values (on a suitably disaggregated basis) between countries

4 Long-run trends in elasticity values over time (ie. is the public transport market becoming more or less elastic?).

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