Lake, M. and **Ferreira, L**. (2002). *Modelling tolls: values of time and elasticities of demand: a summary of evidence.* Physical Infrastructure Centre Research Report 02-01, School of Civil Engineering, Queensland University of Technology, Brisbane.

DEMAND FOR TOLL ROADS: A SUMMARY OF ELASTICITIES, TRAVEL TIME VALUES AND MODELLING APPROACHES

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SUMMARY

This report summarises a review which was prepared as part of a study conducted for the Queensland Department of Main Roads (QDMR) and the Brisbane City Council (BCC) into future transport infrastructure options for Brisbane. The provision of additional cross-river links and the issues associated with the possible use of tolls as the pricing of those links are of special interest in the study. The Transport Research Consortium at QUT has been asked to contribute to this study by:

(a) Reviewing values of time used in demand modelling. Particular emphasis should be placed on the most appropriate values to be used when conducting traffic assignment (analysis of traffic flows using specific paths in the road network); (this is dealt with in Appendix A).

Currently, the Brisbane strategic transport model (BSTM) uses a single value of time for all road users. This value is used to obtain generalised costs of travel and hence to assign an Origin-Destination (O-D) vehicle trip matrix to the road network.

Ideally, to estimate the extent of traffic re-assignment due tolls being introduced on specific links, different values of time should apply to:

- different tripmakers to reflect differences in income levels;
- different trip purposes – 'business' trips and all other trips being the most common distinction made. In this way, commercial vehicle trips, for example, would use a different value of time for assignment purposes.
- different trip distances to reflect the different elasticities of demand to tolls for different trip lengths.

The literature surveyed points to a wide range of VTT used for modelling purposes. However, 40% to 50% of average wage rates seems to be widely accepted for non-'business' trips (where 'business' trips are those made during employers' time). The latter tend to be valued at higher rates of up to 80%-100% of the wage rate. With the current Australian weekly average wage of around $22/hr., this would translate into values of time of between $9-$11/hr. and $18-$22/hr. for 'business' trips. The Brisbane Strategic Transport Model uses a single value of time of $12/hr.

(b) Reviewing the evidence on the elasticities of demand for road tolls in urban networks from elsewhere and reporting on the appropriateness of transferring the results to Brisbane;

The use of tolls to finance capital expenditure on road facilities offers an opportunity to include a component of the toll which can be used to reflect congestion related topics. Road user charges or tolls for the use of congested road space has long been seen by economists as the preferred option to allocate scarce resources efficiently. Such charges have been made politically acceptable when the revenues obtained have been used to fund improvements in public transport services and facilities.

A range of toll elasticities was found in the literature. It would appear that elasticities of between -0.2 and –0.3 could be used in Brisbane as average values. However, there is a wide range of values found for different trip purposes, income levels and overall trip

costs. In addition, the availability of alternative routes which are attractive enough, in terms of levels of service, will have a significant impact on elasticities of demand for tolled roads.

The main options used to undertake traffic assignment with toll estimation remain as put forward in QT (1993), namely:

- Use conventional assignment techniques with generalised costs and treat the toll as an additional cost on a specific link, using an assumed value of time for all drivers;

- Use multi-class assignment with each vehicle class having a different assumed value of time. Values of time for different trip purposes can be used to reflect differences in drivers' perceptions. This option also allows for different toll rates by vehicle class. This option could also see the use of more detailed modelling techniques based on logit type 'diversion' curves. This allows for different classes of vehicle or trip purposes to be modelled separately with the probability of using the tolled facility given by a function of the generalised cost difference between it and its next best alternative.

Whilst there have been advances in the way in which the main software transport planning packages deal with the modelling of tolls, the basic options and their data requirements remain as outlined in QT (1993). The needs identified in that report related to specific surveys to obtain up-to-date data on drivers perceptions of time and operating costs, still remains.

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INTRODUCTION

This review has been prepared as part of a study being conducted for the Queensland Department of Main Roads (QDMR) and the Brisbane City Council (BCC) into future transport infrastructure options for Brisbane. The provision of additional cross-river links and the issues associated with the possible use of tolls as the pricing of those links are of special interest in the study. The Transport Research Consortium at QUT has been asked to contribute to this study by:

(c) Reviewing values of time used in demand modelling. Particular emphasis should be placed on the most appropriate values to be used when conducting traffic assignment (analysis of traffic flows using specific paths in the road network);

(d) Reviewing the evidence on the elasticities of demand for road tolls in urban networks from elsewhere and reporting on the appropriateness of transferring the results to Brisbane;

This report is organised as follows: section 2 gives a brief background on the need for congestion related road user charges. Section 3 deals with the concept of generalised costs; valuation of travel time and elasticities of demand for travel and fuel consumption with respect to changes in fuel price. Corresponding elasticities of public transport fares are also given at this stage. This section ends with a summary of elasticities obtained for toll roads specifically. The issue of modelling approaches to estimate toll road demand is briefly canvassed in section 4. Appendix A deals with the review of values of time used in transport demand modelling.

2. ROAD USER CHARGES AND TOLLS: BACKGROUND

When volume to capacity ratios approach 1, each additional driver imposes costs on all other drivers and on the community which are not priced into the cost of making the trip. The full social costs of congestion, include externalities such as environmental impacts (mainly air and noise pollution), as well as delay and accidents costs. The delay costs of congestion have been estimated by the BTE (1996) for 1995 and projected for 2015 for the main capital cities in Australia. The results, which are summarised in Figure 1, show a significant increase for Brisbane. The use of tolls to finance capital expenditure on road facilities offers an opportunity to include a component of the toll which can be used to reflect congestion related topics. Road user charges or tolls for the use of congested road space has long been seen by economists as the preferred option to allocate scarce resources efficiently. Such charges have been made politically acceptable when the revues obtained have been used to fund improvements in public transport services and facilities.

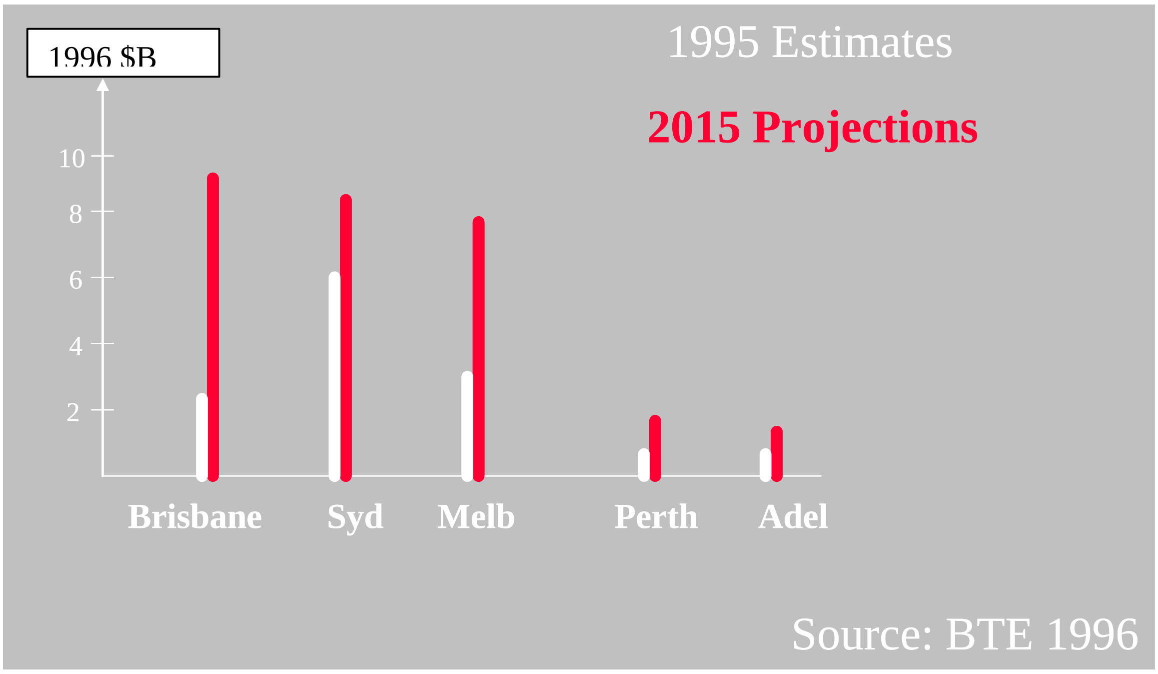


Figure 1. Congestion costs in Australian cities (delays only)

3. ESTIMATING DEMAND FOR TOLL ROADS

3.1 Generalised Costs

The way in which the demand for tolls is usually estimated requires the conversion of travel time, vehicle operating costs, parking charges and tolls into common units using values of time. The latter are normally estimated through surveys (either revealed preference or stated preference approaches). The values of time to be used in this case are related to drivers perceptions rather than average values used for economic evaluation (Figure 2). The values of time used in modelling are summarised in Appendix A. Figure 3 summarises the range of values of time found in the literature. In general the value of time has an elasticity with respect to income of between 0.2 and 0.4.

Trip distance will play a significant role in toll demand estimation. As shown in Figure 4, generalised costs vary with trip distance at different rates for peak and off-peak traffic conditions.

The impact of varying the assumptions related to the value of time and the toll charge are shown in Figures 5 and 6 respectively. The results show how toll cost as a percentage of total trip generalised cost varies with trip distance. The examples shown were obtained using vehicle operating costs and travel speeds typically used in Brisbane.

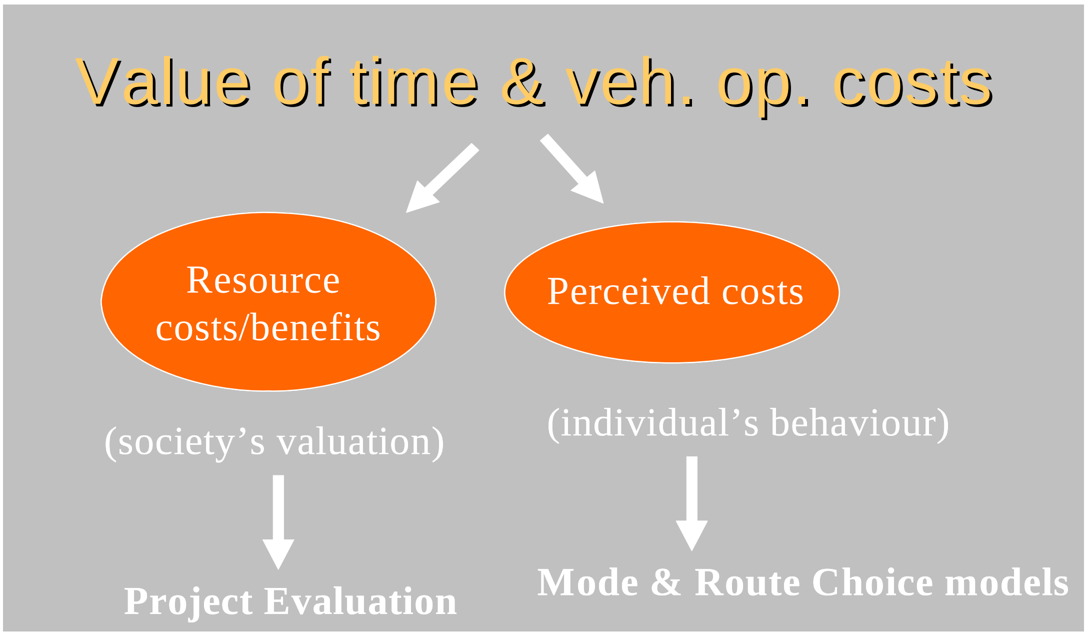


Figure 2. Generalised cost components

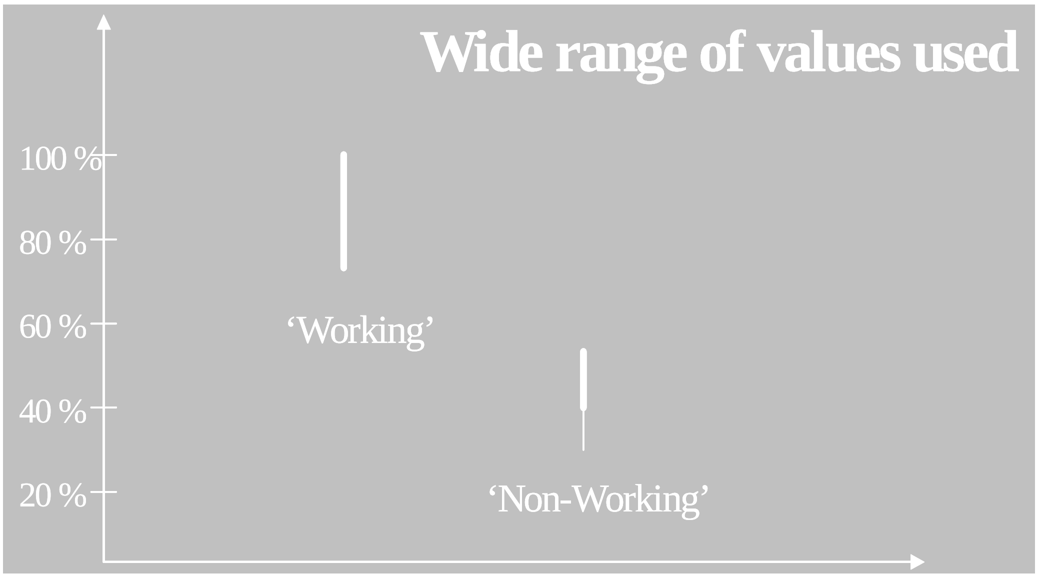


Figure 3. Values of Time as Percent of wage rates

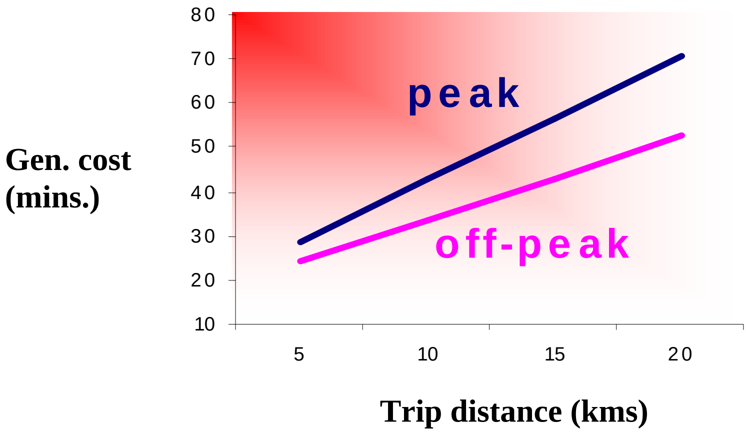


Figure 4. Generalised cost vs trip distance: time of day effects

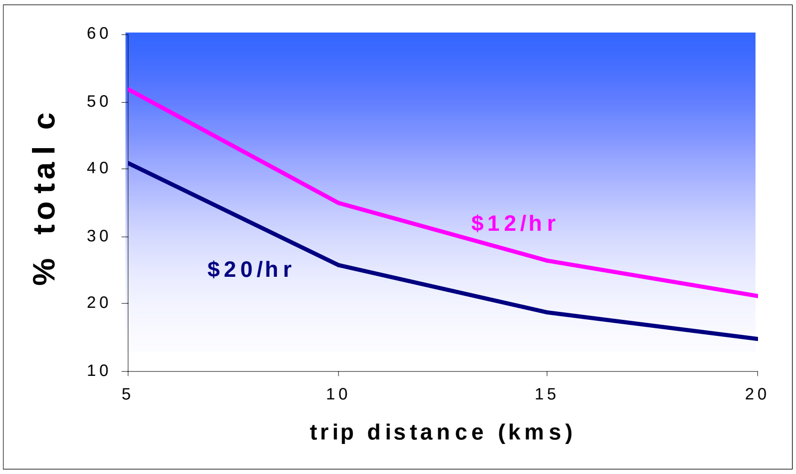


Figure 5. Toll as percent total cost vs trip distance: value of time effect

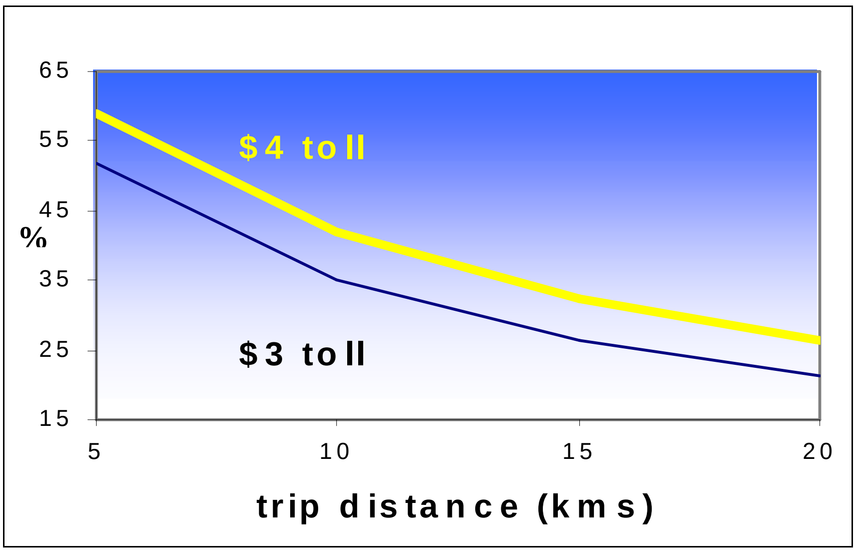


Figure 6. Toll as percent. total cost vs trip distance

3.2 Price Elasticities: Fuel and PT Fares

Figure 7 shows the main range of elasticities of demand for fuel consumption and VKT with respect to fuel price. Whilst VKT very inelastic, particularly in the short run, drivers adjust much more to fuel price rises in relation to fuel consumption, either through more fuel efficient vehicles or better driving techniques to conserve fuel.

The elasticities of demand for public transport trips with respect to fares are shown in Figure 8. Figures available for Brisbane in 2001 are also shown for peak and off-peak bus usage.

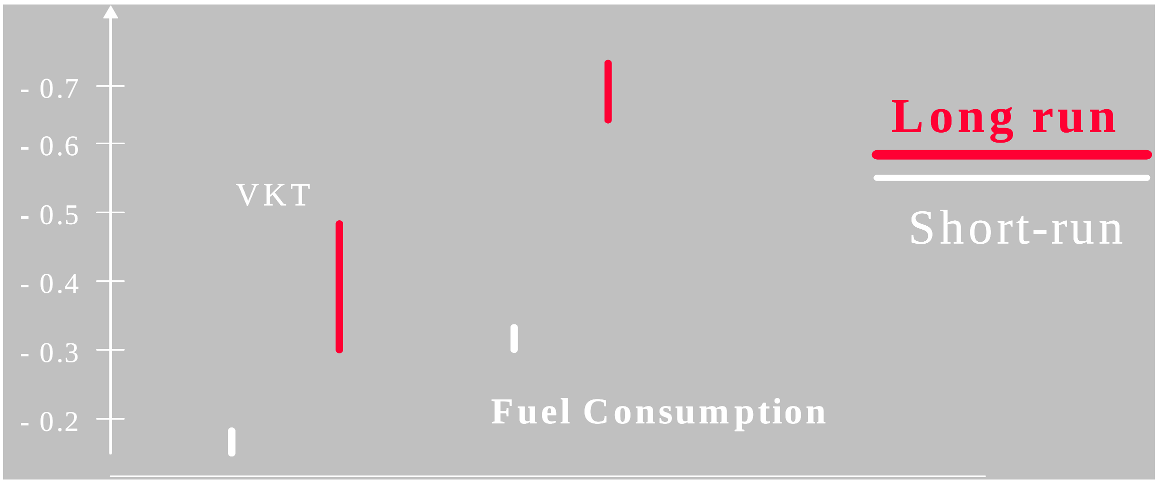


Figure 7. VKT and fuel use elasticities with respect to fuel price

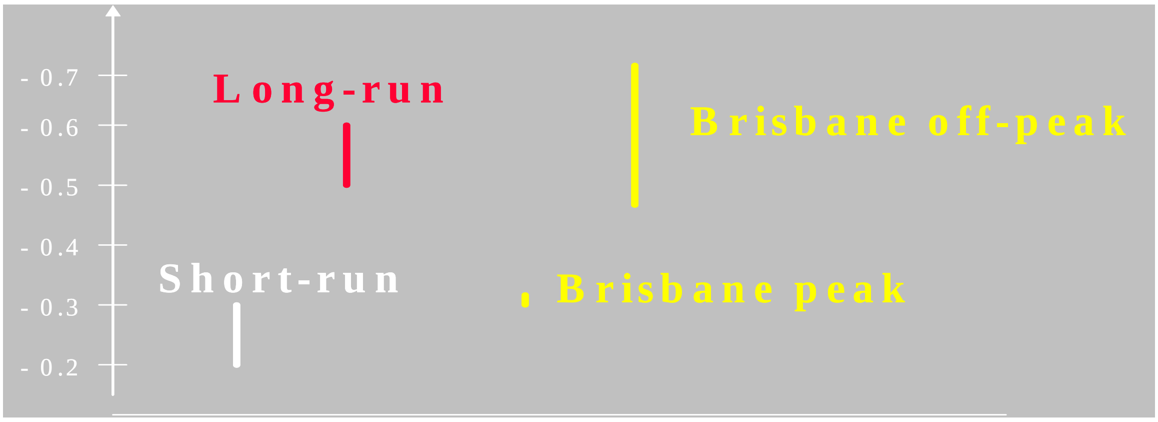


Figure 8. PT fare Elasticities

3.3 Toll Elasticities

There are a number of studies into elasticities and demand modelling for all modes of transport. This review focuses on the studies into elasticities of demand for road tolls. Reviews of the price elasticities for different modes and other factors can be found in Oum et al. (1992) and Goodwin (1992). Goodwin (1992) noted that there had been an increase in elasticities from 1980 to 1990, with a mean elasticity for public transport from 50 studies of -0.41 and a mean from 120 studies for elasticities for petrol consumption of -0.48. Recent research into modal elasticities for Australia includes IPART (1996), Taplin et al. (1997) and Hensher and Louviere (1998).

Jones and Hervik (1992), in investigating toll schemes in Norway, found in one situation after the introduction of a toll the traffic initially dropped, however, returned to the pre-toll level after three months. In another situation, the traffic decreased at a level implying a toll elasticity of -0.40. Motomura and Laoha-Unya (1993) in conducting a study of a proposed toll expressway found a toll elasticity of -0.23 for Bangkok. The demand curves generated suggest a declining demand elasticity with respect to toll levels due to increased traffic congestion and real values of time.

Hirschman et al. (1995) used twelve years of monthly time series data to estimate toll elasticities for two tunnels and six bridges in New York. The median toll elasticity for passenger cars was found to be -0.10, with the values for each bridge and tunnel given in Table 1 by vehicle type. The finding that automobile travel is highly inelastic with respect to toll rates is consistent with most previous travel demand studies. Site specific analysis is advised to derive reasonable forecasts of the impact of new or higher tools on a particular facility, as drivers' responses to tolls depend on many circumstances, and toll elasticities can vary substantially even within the same urban area.

Table 1: Toll Elasticities for New York Tunnels and Bridges

	Brooklyn Battery Tunnel	Queens Midtown Tunnel	Triboro Manhatten Plaza	Triboro Bronx Plaza	White-Stone Bridge	Throg's Neck Bridge	Henry Hudson Bridge	Verrazano Narrows Bridge
Passenger Cars	-0.26	-0.07	-0.03	-0.13	-0.09	0.19	-0.50	-0.10
Light Trucks	-0.54	-0.45	-0.14	-0.07	-0.13	-0.12		-0.17
Heavy Trucks	-0.60	-0.60	0.00	-0.14	-0.09	-0.01		0.20

Source: Hirschman et al. (1995)

Gifford and Talkington (1996) used data from 1979 to 1984 for the Golden Gate Bridge to examine the toll elasticities and the effect of toll increases for some days of the week which result in the tolls varying by day of the week. The cross elasticities were found to be negative, that is a toll increase on 1 day of the week tends to dampen traffic on other days of the week. Travellers respond to time-dependant (day of week) toll increases by reducing their overall travel, not by shifting their travel to reduced cost periods.

Bonsall et al. (1999) investigated behavioural responses to road pricing in the UK, using questionnaires, route-choice and driving simulators, and field trials. It was found from the field trials that for over a third of the journeys the drivers reported that their choice of route and/or departure time on that day was constrained in some way and thus they were not reacting freely to the toll charges. It was concluded that this result highlights the importance of day-to-day constraints on travel behaviour and naive application of elasticities derived in an insufficiently constrained environment will lead to an overprediction of response.

Luk (1999) used the traffic volumes in Singapore before and after a change in the price of the toll to enter the Singapore CBD. The elasticities derived were between -0.19 and -0.58, with an unweighted average of -0.34. Cross price elasticities for bus demand due to toll prices were found to be +0.17 for the toll introduction and +0.8 for the toll increases.

Radovich and Foster (2000) calculated toll elasticities using revealed preference data from a harbour bridge tolled route and a free route in New Zealand. The values which were found are given in Table 2, compared to the values obtained from three other studies. Price elasticities found in US research generally fall in the -0.1 to -0.3 range, while values from the removal of a toll on the Westgate Bridge in Melbourne were estimated at -0.3 for cars and -0.5 for trucks. It is argued that the toll elasticities will depend on two key parameters: the proportion they represent of the overall trip cost; and the availability of alternate routes.

Table 2: Elasticities of 'Harbour Bridge' Demand Comparison

	Time	Toll	Toll [1]	Toll [2] (Oslo)	Toll[2] (Alesund)	Toll[3]
Work	–0.36	–0.14	–1.79			
Personal business	–0.43	–0.15				
School	–0.86	–0.65				
Business	–0.30	–0.10	–0.66			
Social–recreational	–0.44	–0.13				
Leisure	–0.24	–0.10	–0.73			
All veh. type, all purposes	–0.34	–0.10		–0.22	–0.45	–0.17 to –0.37
Private cars, all purposes	–0.28	–0.11				

1 Hensher (1985)
2 Jones (1990)
3 Atkins (1985)

Source: Radovich and Foster (2000)

Figure 9 shows a summary of the range of toll elasticities found in the literature. It would appear that elasticities of between -0.2 and –0.3 could be used in Brisbane as average values. However, there is a wide range of values found for different trip purposes, income levels and overall trip costs. In addition, the availability of alternative routes which are attractive enough, in terms of levels of service, will have a significant impact on elasticities of demand for tolled roads.

Figure 9. Demand elasticities with respect to tolls

4. MODELLING TOLL ROADS

As shown in Figure 10, tolls and road user charges in general have both short and log-term impacts. The latter include destination and location choices, as well as mode choice decisions. However, most modelling exercises are focussed on the shorter-term effects which are mainly in the form of changes to routes chosen and to the start times of trips (if tolls are varied by time of day). The main factors affecting the extent of toll impacts include: total trip costs; availability of alternative routes; and values of time used in the various modelling stages.

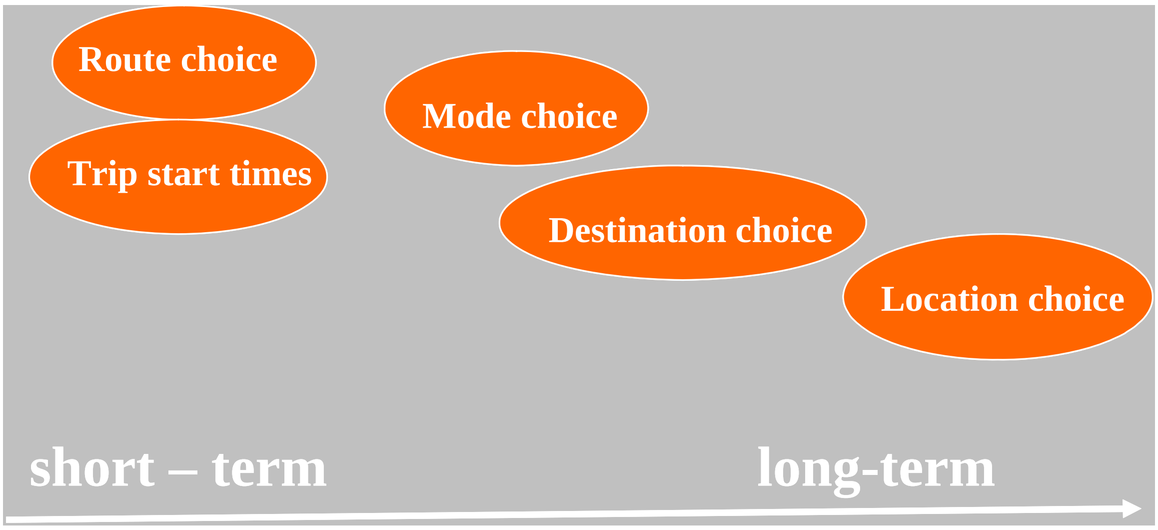


Figure 10. Modelling Tolls – short vs long term impacts

Research from the UK (Bonsall et al. (1999) and elsewhere suggests that:

- a fixed charge is preferred to one which is unknown at the at the start of the trip;
- a charge based on time spent in congested conditions is very unpopular;
- significant trip numbers are constrained either by time of departure or choice of route;
- high income earners are less sensitive to tolls; and
- females tend to be more reluctant to change routes.

QT (1993) conducted an international survey to establish the modelling approaches used for travel demand forecasting. The survey included national and regional governments, research establishments, consultants and toll facility operators located in Australia, North America, Europe and other countries. As a result, the modelling approaches which could be adopted in Queensland were put forward, together with the associated data needs, in terms of additional survey work which might be necessary to update values of time by type of user. The main options used to undertake traffic assignment with toll estimation remain as put forward in QT (1993), namely:

- Use conventional assignment techniques with generalised costs and treat the toll as an additional cost on a specific link, using an assumed value of time for all drivers;

- Use multi-class assignment with each vehicle class having a different assumed value of time. Values of time for different trip purposes can be used to reflect differences in drivers' perceptions. This option also allows for different toll rates by vehicle class.

- Use more detailed modelling techniques based on logit type 'diversion' curves. This allows for different classes of vehicle nor trip purposes to be modelled separately with the probability of using the tolled facility given by a function of the generalised cost difference between it and its next best alternative.

Whilst there have been advances in the way in which the main software transport planning packages deal with the modelling of tolls (eg: separate module in VISUM using logit like curves by type of vehicle/user), the basic options and their data requirements remain as outlined in QT (1993).

The need identified in that report related to specific surveys to obtain up-to-date data on drivers perceptions of time and operating costs, still remains.

5. REFERENCES

Akcelik & Associates Pty Ltd (2000) aaSIDRA User Guide, Akcelik & Associates Pty Ltd, Greythorn, Victoria, www.aatraffic.com.

Bates, J., Polak, J., Jones, P and Cook, A. (2001) The Valuation of Reliability for Personal Travel, *Transportation Research E*, 37(2-3), 191-229.

Bonsall, P., Cho, H-J., Palmer, I and Thorpe, N. (1999). Experiments To Determine Drivers' Response to Road User Charges, *Proceedings of the European Transport Conference*, PTRC, Cambridge, UK.

BTE (1996). Transport and greenhouse: costs and options for reducing emissions, *Report 94*, AGPS, Canberra.

Bristow, A. and Nellthorp, J. (2000) Transport Project Appraisal in the European Union, *Transport Policy*, 7(1), 51-60.

Calfee, J. and Winston, C. (1998) The Value of Automobile Travel Time: Implications for Congestion Policy, *Journal of Public Economics*, 69(1), 83-102.

Gifford, J. and Talkington, S. (1996). Demand Elasticity under Time-Varying Prices: case Study of Day-Of-Week Varying Tolls on Golden Gate Bridge, *Transportation Research Record* 1558, 55-59.

Goodwin, P. (1992) A Review of New Demand Elasticities With Special Reference to Short and Long Run Effects of Price Changes, *Journal of Transport Economics and Policy*, 26(2), 155-169.

Gunn, H. (2001) Spatial and Temporal Transferability of Relationships between Travel Demand, Trip Cost and Travel Time, *Transport Research E,* 37(2-3), 163-189.

Hayashi, Y. and Morisugi, H. (2000) International Comparison of Background Concept and Methodology of Transportation Project Approval, *Transport Policy*, 7(1), 73-88.

Jones, P. and Hervik, A. (1992) Restraining Car Traffic in European Cities: An Emerging Role for Road Pricing, *Transportation Research A*, 26(2), 133-145.

Hensher, D. (2001a) Measurement of the Valuation of Travel Time Savings, *Journal of Transport Economics and Policy,* 35(1), 71-98.

Hensher, D. (2001b) The Sensitivity of the Valuation of Travel Time Savings To the Specification of Unobserved Effects, *Transport Research E*, 37(2-3), 129-142.

Hensher, D. (1998) Extending Valuation to Controlled Value Functions and Non-Uniform Scaling with Generalised Unobserved Variances. In: *Theoretical Foundations of Travel Choice Modelling*, Garling, T., Laitila, T. and Westin, K. (Eds), Pergamon, Elsevier Science, Oxford, UK.

Hensher, D. (1994) Stated Preference Analysis: State of Practice, *Transportation*, 21(2), 107-134.

Hensher, D. and Louviere, J. (1998). A Comparison of Elasticities from Multinomial Logit, Nested Logit and Heteroscedastic Extreme Value SP-RP Discrete Choice Models, *Institute of Transport Studies Working Paper ITS-WP-98-3 ITS*, Institute of Transport Studies, University of Sydney, Sydney, Australia.

Hirschman, I., McKnight, C., Pucher, J., Paaswell, R. and Berechman, J. (1995). Bridge and Tunnel Elasticities in New York, *Transportation*, 22, 97-113.

Independent Pricing and Regulatory Tribunal of New South Wales (IPART). (1996). Estimation of Public Transport Fare Elasticities in the Sydney Region, *Research Paper no. 7* IPART, Sydney, Australia.

Lam, T. and Small, K. (2001) The Value of Time and Reliability: Measurement from a Value Pricing Experiment, Transportation Research B, 37(2-3), 231-251.

Lee, D. Jr (2000) Methods for Evaluation of Transportation Projects in the USA, *Transport Policy*, 7(1), 41-50.

Li, M. (1999) Estimating Congestion Toll By Using Traffic Count Data – Singapore's Area Licensing Scheme, *Transportation Research E*, 35, 1-10.

Louviere, J., Hensher, D. and Swait, J. Jr (2000) *Stated Choice Methods*, Cambridge University Press, Cambridge, UK.

Luk, J. (1999). Electronic Road Pricing in Singapore, *Road and Transport Research*, 8(4), 28-40.

McEvoy, J., Prince, A. and Ferreira, L. (1995) Generalised Cost Parameters for Travel Demand Forecasting in Queensland, *Road and Transport Research* 4(2), 76-87.

Morisugi, H. (2000) Evaluation Methodologies of Transportation Projects in Japan, *Transport Policy*, 7(1), 35-40.

Motomura, Y. and Laoha-Unya, S. (1993). Derivation of Value of Time and Traffic Demand Curves in Bangkok, *Transportation Research Record* 1395, 33-38.

Oum et al. (1992). Concepts of Price Elasticities of Transport Demand and Recent Empirical Estimates, *Journal of Transport Economics and Policy*, 26(2), 139-154.

Polak, J. and Jones, P. (1997) Using Stated-Preference Methods to Examine Traveller Preferences and Responses. In: *Understanding Travel Behaviour in an Era of Change*, Stroper, P. and Lee-Gosselin, M (Eds), Pergamon, Elsevier Science, Oxford, UK.

Quinet, E. (2000) Evaluation Methodologies of Transportation Projects in France, *Transport Policy*, 7(1) 7-16.

QT (1993). SEQ Travel Cost Study. SKM and Ferreira, L. Queensland Transport, Transport Studies Section, Brisbane.

Radovich, B. and Foster, J. (2000) Urban Travel Time Value – Some New Zealand Findings, *Road & Transport Research*, 9(3), 27-39.

Rothengatter, W. (2000) Evaluation of Infrastructure Investments in Germany, *Transport Policy*, 7(1), 17-25.

Senna, L. (1994) The Influence of Travel Time Variability on the Value of Time, *Transportation*, 21(2), 203-228.

Smith, B. (1999) The Goods/Leisure Trade-Off and the Value of Travel Time Savings, *Road & Transport Research*, 8(3), 74-78.

Taplin, J., Hensher, D. and Smith, B. (1997). Imposing Symmetry on a Complex Matrix of Commuter Travel Elasticities, *Institute of Transport Studies Working Paper, ITS-WP-97-15*, Institute of Transport Studies, University of Sydney, Sydney, Australia.

Vickerman, R. (2000) Evaluation Methodologies for Transport Projects in the United Kingdom, *Transport Policy*, 7(1), 7-16.

Wardman, M. (2001) A review of British evidence on time and service quality valuations, *Transportation Research Part E*, 37(2-3), 107-128.

Wardman, M. (1998) The value of travel time: A review of British evidence, *Journal of Transport Economics and Policy*, 32(3), 285-316.

APPENDIX A: VALUES OF TIME TO BE USED IN TRAVEL DEMAND MODELLING

A1. INTRODUCTION

The values of time to be used at the demand modelling stage are dealt with in Section A2. This is followed by a brief discussion of travel time values to be used for transport evaluation of projects. Finally some recommendations are put forward in Section A4.

The value of travel time (VTT) to be used for travel demand purposes should be distinguished from those to be used for the purposes of evaluating transport projects and strategies. When determining the costs and benefits for an economic assessment, travel costs need to reflect society's valuation, whereas in travel demand modelling there is a need to reflect individuals' perceive valuation of travel time. Travel time values are used in modelling to reflect the behaviour of tripmakers when decisions are made related to the choice of destination (trip distribution), mode used (modal-split) and route taken (traffic assignment). It is standard practice to use 'generalised cost' as a means of including the various attributes of a trip, such as travel time and out-of-pocket expenses, in a single cost function. For this reason, values of time are used to convert time units into monetary equivalent values.

Although this report focuses on a review of the values of time for 'behavioural' purposes used in Australia and elsewhere, evaluation travel time values are also included. The VTT for private vehicle travel is of most interest here, in particular related to the traffic assignment implications of toll pricing schemes. Values for other modes, such as public transport and walking, the values of reliability (VOR) are only briefly discussed in relation to relevant studies reviewed here.

Unless stated otherwise, all monetary values are expressed in terms of Australian dollars.

A2. PERCEIVED OR 'BEHAVIOUR' VALUES OF TIME

The research into the VTT discussed below can be segregated into three main categories, namely:

- Empirical studies to determine VTT using either stated preference (SP) techniques or revealed preference (RP) approaches. SP rely on surveys of users or potential users of a transport facility, in which respondents are asked to choose between travel time, travel cost and other trip attributes, in a series of hypothetical situations. Trade-offs are recorded between time and cost and values of time are derived from the calibration of logit type choice models. Hensher (1994) gives a discussion of SP, including a description of different SP methods such as rating, rank-order and choice. Alternatively, RP techniques can be used based on actual choice recorded for respondents where those choice occurred in the course of making actual trips;

- A review of the VTT used nationally or internationally; and

- A review of research into the values of 'business' time. This refers to trips which are being made in the course of work and is often based on the prevailing wage rates.

McEvoy et al. (1995) conducted an international survey to establish the appropriate generalised cost parameters to be used for travel demand forecasting in Queensland. The survey included national and regional governments, research establishments, consultants and toll facility operators located in Australia, North America, Europe and other countries. Many respondents indicated the use of a single VTT for all trip purposes or market segments. For home based work travel for 1993, the mean value was approximately $8/hour. The ranges were: Australia: $4.20-$13.60; overseas $2.20-$18.50; and Queensland: $6.40-$10.40.

For business travel in private vehicles, the VTT varied widely, with $4.20-$29 used in Australia and $2.20-$26.70 overseas. It was found that the value of $10.70 used in Queensland was consistent with the mean values. The values of time found for public transport modelling are given in Table 3, relative to in-vehicle time.

Table 3: Transport VTT Relative To In-Vehicle Time (1.0)

		Waiting		Walking		In Train		In Bus	
	No. of Values	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Australia	6	1.02 - 2.50	1.86	1.30 - 2.50	1.86	0.94 - 1.00	0.97	1.00 - 1.08	1.02
Other	11	1.80 - 2.60	2.13	1.00 - 2.50	1.92	1.00 - 1.30	1.02	1.00 - 1.50	1.04
Combined			2.07		1.90		1.01		1.04
Qld			1.02		1.50		1.00		1.08

Source: McEvoy et al. (1995)

Polak and Jones (1997) report that the growth in popularity of SP methods is largely due to the perceived advantages compared to analysis based solely on RP data, including:

- The ability to reduce or eliminate statistical problems such as multicollinearity and lack of variance in explanatory variables;
- The scope to include attitudinal and qualitative factors that might be difficult or impossible to ascertain from RP data;
- The capacity to assess users' preferences and responses to entirely new products and services or to changes the characteristics of existing products.

Calfee and Winston (1998) estimated VTT using a SP survey of 1170 long distance (trips greater than 15 kms) private vehicle commuters in congested conditions in major U.S. cities. The SP ranking survey included the time/toll cost trade-off. The value of congested time ranged from 3.1 to 5.5 $US per person-hr. (14 to 26% of the gross hourly wage). The VTT increased with income, the higher income commuters (125K – 175K $US pa.) having a VTT of $US7.1 per person-hr., compared with $US3.1 per person-hr. for lower income respondents (7.5K – 12.5K $US pa.). It was found that the VTT are low and insensitive to travel conditions and to how toll revenues are used. It was concluded that the most likely reason for the low VTT is that commuters that have a high VTT commute shorter distances and were not included in this study.

Hensher (1998) used SP techniques with data from six capital cities in Australia to estimate values of time. The results obtained ranged from $6.5-$7.2 per person-hr. for in-vehicle time and $3.4-$7.5 per person-hr. for public transport time. It was found that the age of the commuter, personal income and car availability influenced the VTT. However, other socio-economic variables, such as occupation, employment status, sex, city of residence, drivers licence status and highest level of education, had no significant influence.

The SP data used by Hensher (1998) was also used by Smith (1999) to estimate VTT for different modes. The results are shown in Tables 2 and 3. VTT ranging from around 40% to 50% of the wage rate for full time employees were obtained.

Table 4: VTT for Australian Capital Cities ($/hr.) by Annual Income ($000)

Income	9	25	35	45	55	65	80
VTTS full time auto	2.11	5.87	8.22	10.56	12.91	15.26	18.78
VTTS full time public transport	2.11	5.87	8.22	10.56	12.91	15.26	18.78
VTTS Part time auto	1.83	5.08	7.12	9.15	11.18	13.22	16.27
VTTS Part time Public transport	1.83	5.08	7.12	9.15	11.18	13.22	16.27

Source: Smith (1999)

Wardman (1998) conducted an extensive review of 105 studies conducted in the UK from 1980 to 1996 into the value of in-vehicle travel time. These studies were based on either SP or RP data. A total of 444 estimates of VTT resulted, with the vast majority from SP and only 6% obtained from RP. Of the SP models, the choice exercises comprise 71% of the VTT and dominate the later SP models, as they are considered to provide more reliable data than ranking studies, since they are simpler and more closely resemble the actual decision process. It was found that the SP and RP values are on average very similar, though there is much more variation in the RP values.

Table 5: VTT for Australian Capital Cities ($/hr.) by Length of Journey

income	Length of Journey	full time auto	part time auto	full time transit	part time transit
9	short	2.11	1.85	2.01	1.77
9	medium	2.00	1.74	2.18	1.92
9	long	2.16	1.80	0.96	0.74
25	short	5.49	4.81	4.58	4.00
25	medium	5.82	5.02	4.58	4.02
25	long	6.25	5.20	5.12	4.52
35	short	7.57	6.63	6.16	5.36
35	medium	7.98	6.88	6.29	5.51
35	long	9.18	7.69	6.44	5.65
45	short	9.81	8.59	7.75	6.73
45	medium	10.94	9.40	7.67	6.69
45	long	11.16	9.44	8.05	7.05
55	short	11.89	10.41	8.02	6.72
55	medium	12.85	11.09	9.61	8.39
55	long	14.63	12.20	9.77	8.55
65	short	14.18	12.40	-	-
65	medium	16.02	13.73	-	-
65	long	17.71	14.88	12.80	-
80	short	17.21	15.07	12.56	10.73
80	medium	19.01	16.36	13.62	-
80	long	21.22	17.93	14.05	-

Source: Smith (1999)

The VTT from the investigation are shown in Table 4. The first values, (1), are unadjusted, whilst the second values, (2), are adjusted for changes in GDP. The non-business travel VTT was found to correspond well with the 6.4 pence/minute recommended by UK Department of Transport. The VTT was found to be 35% higher for commuting than leisure travel in London and the South East and 14% higher elsewhere. However, if no geographical distinction was made a 25% increase for commuting versus leisure trips was estimated to be reasonable. The results for business trips show a VTT of 24.8 pence/minute for inter-urban travelers and 21.5 pence/minute when including urban travellers. Wardman (1998) also investigated the effect of a number of variables on the VTT, including GDP, travel distance, journey purpose, study aim and mode.

Bonsall et al. (1999) investigated behavioural responses to road pricing in the UK, using questionnaires, route-choice and driving simulators, as well as field trials. It was found that when a charge could be avoided by changing routes, diversions are made as if time were valued at about 9.3 pence per minute. This implies a higher VTT than was found from the review of Wardman (1998), as shown in Table 4.

Table 6: The VTT from British Studies (pence/minute)

	All 1	All 2	Business 1	Business 2	Non-Business 1	Non-Business 2
Mean	7.26	7.71	20.16	21.43	5.64	5.98
SD	8.64	9.12	16.24	16.92	3.05	3.26
Standard Error	0.40	0.43	2.03	2.11	0.25	0.27
Minimum	0.71	0.74	2.58	2.70	0.92	0.97
10%	1.84	1.93	5.09	5.12	2.04	2.16
25%	2.92	3.01	7.59	7.90	3.44	3.58
50%	4.91	5.13	14.23	14.84	4.99	5.41
75%	7.76	8.32	29.06	31.92	7.59	7.99
90%	13.26	14.53	52.03	55.67	9.61	10.13
Maximum	64.44	68.26	64.44	68.26	18.32	18.50

Source: Wardman (1998)

Wardman (2001) continued his research to include a number of other travel types, such as walking and waiting time, as shown in Table 5. These values are given as a percentage of in-vehicle time.

Table 5: The VTT in the UK Relative to In-Vehicle Time (1.0)

	Mean	S.D.	S.E.	10%	50%	90%	Obs
Walk time	1.66	0.71	0.06	0.90	1.52	2.67	140
Access time	1.81	0.75	0.10	0.88	1.88	2.70	52
Walk and wait time	1.46	0.79	0.10	0.61	1.31	2.43	64
Wait time	1.47	0.52	0.09	0.94	1.33	2.19	34
Adjustment time	0.72	0.64	0.09	0.30	0.50	1.30	56
Headway	0.80	0.46	0.04	0.27	0.70	1.41	145
Search time	1.38	0.52	0.17	0.79	1.22	2.26	10
Late time	7.40	3.86	1.16	1.94	8.00	14.00	11
Delay time	1.48	0.32	0.07	1.04	1.43	2.01	21
Interchange (INTPEN)	17.61	10.93	4.13	3.91	13.52	31.70	8
Interchange (INTFULL)	33.08	22.73	4.64	10.60	28.41	70.47	23
Interchange (INTPREM)	34.59	25.88	6.46	9.5	27.53	66.70	16

Source: Wardman (2001)

Li (1999) used a number of different estimates of the VTT, based on the average wage rate, to determine an appropriate toll value. Four different wage rates were calculated: the average wage rate; the average wage rate of private vehicle owners; the average wage rate including bonuses; and the average wage rate per vehicle. Three different factors to convert the wage rates to VTT were considered. The first was 50% of the wage rate, based on a 1988 empirical study that found that the VTT was 47-49% of the average wage rate. A later study found that the VTT for private vehicle owners was 67% of the average wage rate. The third factor contained an arbitrarily selected higher value for waiting time (75%) than in-vehicle time (67%).

Radovich and Foster (2000) conducted a RP survey on two parallel bridges in New Zealand, one with and one without a toll. A discussion is given on SP versus RP surveys, with the comment that SP surveys can also produce biased results, for example, due to public resistance to a new or increased toll. The VTT, by trip purpose, are shown in Table

6. These were then segregated into leisure or work by income, as shown in Table 7. The average VTT to be used for travel demand forecasting, based on the survey and flow rates of vehicle types, were then concluded to be 10 (am), 12 (inter-peak) and 11 (pm) $NZ/hr.

The default values to calculate the VTT (average income, time value factor and average vehicle occupancy) used in the SIDRA model are given in Table 8, Akcelik & Associates (2000).

Table 6: VTT in New Zealand by Trip Purpose ($NZ)

Trip Purpose	$/Hour	% Mean Hourly Rate	# Observ.
Work	8.35	34	1442
Personal Business	9.64	44	717
School	4.50	20	98
Social-Recreational	10.49	48	1230
Leisure	7.53	34%	2097
Employer’s Business	17.66	80	730

Source: Radovich and Foster (2000)

Table 7: VTT in New Zealand by Trip Purpose and Income

Income	Trip Purpose	$/Hour	% Mean Hourly Rate	Observations
< 20	Work	4.10	45	75
	Leisure	4.68	51	351
20 – 30	Work	6.99	46	164
	Leisure	4.26	28	289
30 – 50	Work	9.97	41	405
	Leisure	12.21	50	205
50 – 70	Work	8.29	23	264
	Leisure	11.17	31	104

Source: Radovich and Foster (2000)

Table 8: SIDRA Default VTT: Australia, New Zealand and the U.S.

	Australia $AUD	New Zealand $NZD	U.S. $USD
Average Income (full time adult average hourly total earnings) in $/hour	20.00	16.80	15.00
Time value factor as a proportion of average hourly income	0.60	0.90	0.40
Average vehicle occupancy in persons per vehicle	1.5	1.5	1.2
VTT (time value factor * average income)	12.00	15.12	6.00
VTT (time value factor * average income * vehicle occupancy)	18.00	22.68	7.20

Source: Akcelik & Associates Pty Ltd (2000)

Louviere et al. (2000) calculated the VTT based on an SP survey conducted by Hensher in 1994 in Sydney, which gave the time/toll cost trade-off. The VTT values by trip purpose are given in Table 9. Hensher (2001a) conducted an SP survey to determine the VTT for non-business private vehicle drivers on long distance trips in New Zealand. Hensher (2001b) reported that there has been an 'explosion' of studies using a mixture of RP and SP to derive VTT. According to Hensher (2001a), the estimates of VTT from SP are sensitive to:

- The number of alternatives in a choice set;
- The number of choice sets evaluated; and
- The range and levels of the time and cost attributes begin traded.

VTT values were found using three models, with mean VTT for long distance trips of 8.7 and 9.4 $NZ/hr. The VTT was also segregated into free flow time, slowed down time, stop/start time and uncertainty, in addition to fuel and toll costs.

Table 9: The VTT for Sydney By Trip Purpose – 1994 data ($/person-hr.)

Toll	Time = 5 mins	Time = 7.5 mins	Time = 10 mins
Private commute			
Pinc = $19.81/hr			
$1	**4.35** (2.07)	3.29 (2.01)	2.65 (1.96)
$1.5	8.18 (2.44)	6.20 (2.33)	4.99 (2.30)
$2	12.01 (2.81)	9.10 (2.73)	7.33 (2.65)
Business commute			
Pinc = $26.17/hr			
$1	**7.07**	4.78	3.61
$1.5	12.81	8.66	6.54
$2	18.55	12.55	9.48
Travel as part of work			
Pinc = $23/hr			
$1	**4.59**	3.08	2.31
$1.5	10.50	7.04	5.29
$2	16.41	11.00	8.27
Social-recreation travel			
Pinc = $18.4/hr			
$1	**5.68**	5.23	4.85
$1.5	6.70	6.17	5.72
$2	7.73	7.12	6.60
Other personal business			
Pinc = $18.86/hr			
$1	**8.33**	5.57	4.19
$1.5	14.27	9.55	7.17
$2	20.21	13.52	10.16

Notes: Pinc = average hourly personal wage rate; Time refers to the trip length for the part of the trip where a toll would be incurred (and to the door-to-door trip time). Each VTTS (e.g., 4.35) is expressed in dollars per person hour. VTTS in brackets for private commute are derived from a model estimated on actual levels of attributes.

Source: Louviere et al (2000)

Lam and Small (2001) obtained VTT and values of reliability (VOR) based on a RP survey of commuters in California in 1998 who chose between a free and a variably tolled route. A VTT of 22.9 $US/hr. was found, with the value of reliability 15.1 $US/hr. for men and 31.9 $US/hr. for women. These values represent 72%, 48% and 101% of the average wage rate, respectively. Other research into VOR includes Senna (1994), who calculates VOR as percentages of the VTT, and Bates et al. (2001), who presents a review of the theory of the VOR, including some of the recent empirical research in this area.

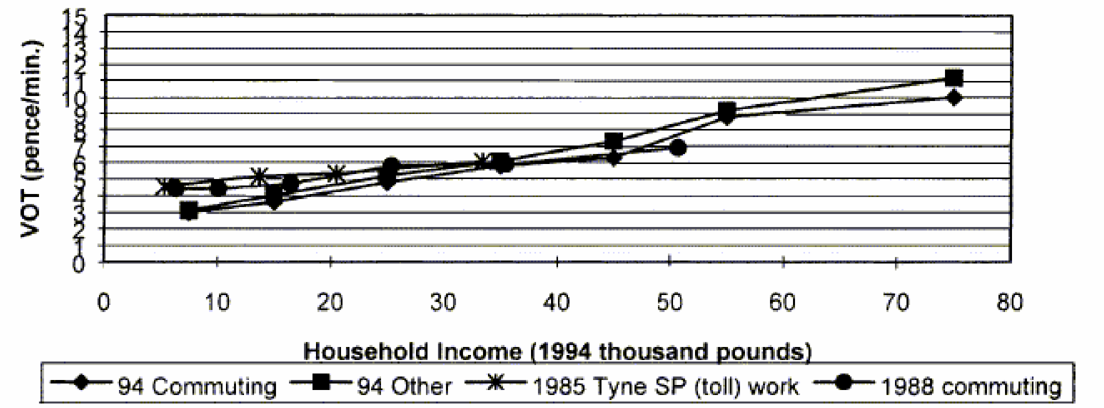
Gunn (2001) collated results from major RP and SP studies in Europe to investigate the issue of temporal and spatial transferability of VTT. The SP studies were confirmed the stability of the major relationships between VTT and explanatory variables of income, personal and household characteristics, between time periods and across regions. For example, comparing the Dutch and UK SP studies, the income trends were found to be quite similar, as shown in Figure 3.

The main conclusions drawn from this latter comparison of the SP studies were:

- Income is clearly related to VTT and must be incorporated into predictive models;
- The VTT increases with journey duration;
- Small time savings seem not to be valued at all;
- Business travel time seems to be changing in nature and mobile phones appear to be affecting VTT;
- The VTT for female commuters has increased over the decade from 1988, whilst the VTT for female leisure travelers has declined;
- Older travellers continue to have lower VTT, but over time this imbalance is correcting itself.

It was speculated that geographic and historic factors might be able to be generalised to obtain spatial adjustments to improve model transferability. The danger of comparing average VTT between studies with different designs was emphasised.

Figure 3: The VTT for the Dutch 1988 Versus UK 1985 and 1994 Results (1994 pounds)



Source: Gunn (2001)

A3. VALUES OF TIME USED IN PROJECT EVALUATION

This section provides a review of values of time used when evaluating transport projects. A discussion of whether and how to use VTT in the evaluation of transport is provided in Mackie et al. (2001). Issues considered include the major influences on an individual's VTT, the appropriateness of a single value of time, whether small travel time savings should be valued and the increase in the VTT over time. The main conclusions of this study were that time is a scare resource and should be always valued. However, the direct use of values of time based on the willingness to pay concept is inappropriate for social cost-benefit appraisal of projects.

Vickerman (2000) reports that the VTT used in the UK is based the assumption of a constant marginal unit value of time, regardless of time saved or income. The highly segmented VTT, which are given in Table 10, are subject to 1.6% to 3.0% annual growth.

Table 10: The VTT Used for Transport Project Appraisal (UK)

Vehicle	Occupancy	Time mode	Value of time (pence per hour)	
			Per occupant	Per vehicle
Car (working)	1.00 driver	Working	1289.8	
	0.11 passenger	Working	1070.6	1407.6
Car (non-work)	1.00 driver	Non-working	315.0	
	0.74 passenger	Non-working	315.0	548.1
Average car	1.00 driver	Assumes 14.6%		
	0.65 passenger	in work mode		673.6
LGV (working)	1.00 driver	Working	1003.1	
	0.42 passenger	Working	1003.1	1424.4
LGV (non-work)	1.00 driver	Non-working	315.0	
	0.60 passenger	Non-working	315.0	504.0
Average LGV	1.00 driver	Assumes 72%		
	0.47 passenger	in work mode		1166.7
OGV	1.00 driver	Working	945.0	945.0
PSV	1.00 driver	Working	983.1	
	12.1 passenger	Non-working	315.0	
	0.1 passenger	Working	1064.4	4901.0
Average vehicle				784.4

Source: Vickerman (2000)

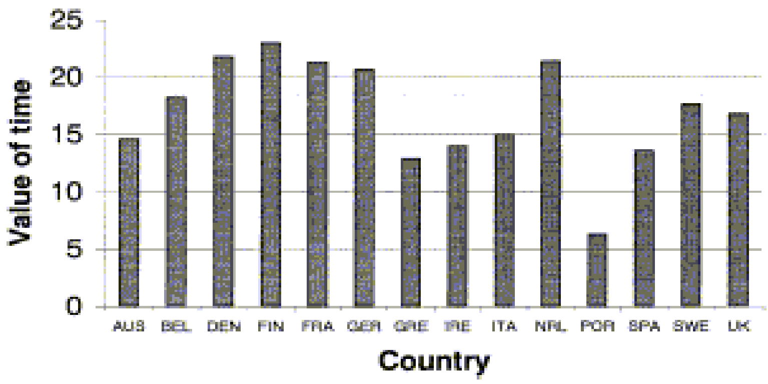
Rohengatter (2000) explains that the VTT used in Germany for transport project evaluation is based on two sources: (1) average wage rates and (2) stated preference analysis to generate a differentiated structure dependant on travel purpose, mode and vehicle category. The VTT used in France is independent of individual income due to political and ethical considerations and is equal to the hourly wage rate, growing 1.5% annually (Quinet, 2000).

Morisugi (2000) provides the VTT used in Japan for transport project evaluation, based on the average wage approach, with values increased on railways for transfer time (double) and for traffic congestion. The VTT for vehicles is divided into working or holidays, with holidays approximately 10% higher to account for higher premium of holiday working wage, higher price of recreational facilities and the higher occupancy rate of passenger cars.

Lee (2000) discusses the VTT used for project evaluation in the US where standard values tend not to be used.

Bristow and Nellthorp (2000) found that the value of time for project evaluation was distinguished by different categories throughout the European Union, including: by person or vehicle; journey purpose; mode; distance; class of travel; and type of vehicle. A range of 6.3-23 euro/hr. for working travel by car and 2-8 euro/hr.for non-work time was identified, as can be seen in Figure 2. Some countries, for example Austria, Belgium, France and Greece, do not use separate values for work and non-work time. Distinguishing between working and non-working time, the wage rate is considered a valid measure for working time, while the Netherlands and Sweden combining an estimate of the value of the time savings to the employer and employee. For non-working time, it was observed that there is no obvious market and valuation is more complex, with methods depending on individuals' willingness to pay. Most countries use a non-working VTT of 10-42% of the working time value.

Figure 4: The VTT for working travel by private vehicle in Europe (Euro/hr.)



Source: Bristow and Nellthorp (2000)

Hayashi and Morisugi (2000) provide a comparison of the project evaluation methodologies used in the UK, USA, France, Germany and Japan. The VTT is based on the wage rate for all these countries, however, the actual value of time varied with different factors, such as vehicle type and trip purpose, as can be seen in table 11.

In summary, the VTT used for project evaluation is:

- Generally based on the average wage rate, mainly due to equity issues;
- Generally given in different segmentations. For example by: person type or income; journey purpose; travel mode; trip distance; and type of vehicle; and
- Commonly distinguished between non-working and working time, although, there is no consensus on how non-working time should be valued. Most countries use a lower value for non-working time, with Japan being the exception.

Table 11: Values of Time Used in Project Evaluation

	UK	France	Japan	USA	Germany
Value of Time	Based on working/ non working, driver/ passenger and type of vehicle	Values for working and non working the same	Based on type of vehicle, and weekday/ holiday, includes transfer time and congestion factors for rail	Depends on working (wage rate) or non working (fraction of wage rate)	Categories of trip purpose and mode type (bus, car, rail, truck)
Approximate Value of Time ($US/hr) working time, car travel	18	21	20	8 – 40	20

Source: Hayashi and Morisugi (2000)

A4. CONCLUSIONS

Both SP, RP and a combination of the two approaches have been used to estimate VTT. The SP technique has seen wider application mainly because it is more difficult to find good RP data which relies on the availability of actual travel choices where time and cost are traded-off. The major advantage of the SP approach is that it can test a range of options which may not be currently available.

Studies that considered the income levels all found VTT increased with income, as would be expected. Therefore, a single point estimate of the VTT is unlikely to produce accurate demand or driver response when modelling toll options.

Currently, the Brisbane strategic transport model (BSTM) uses a single value of time for all road users. This value is used to obtain generalised costs of travel and hence to assign an Origin-Destination (O-D) vehicle trip matrix to the road network. Ideally, to estimate the extent of traffic re-assignment due tolls being introduced on specific links, different values of time should apply to:

- different tripmakers to reflect differences in income levels;
- different trip purposes – 'business' trips and all other trips being the most common distinction made. In this way, commercial vehicle trips, for example, would use a different value of time for assignment purposes.
- different trip distances to reflect the different elasticities of demand to tolls for different trip lengths.

Whilst it is possible to undertake traffic assignment using different values of time for different vehicle classes, the use of income levels and trip distances would require a more detailed treatment. For example, selected links could be analysed to determine the proportion of trips from each O-D pairs being used. Diversion curves could then be used to re-assign traffic on the basis of time savings and associated values of time for each trip distance category.

The literature surveyed points to a wide range of VTT used for modelling purposes. However, 40% to 50% of average wage rates seems to be widely accepted for non-'business' trips (where 'business' trips are those made during employers' time). The latter tend to be valued at higher rates of up to 80%-100% of the wage rate. With the current Australian weekly average wage of around $22/hr., this would translate into values of time of between $9-$11/hr. and $18-$22/hr. for ‘business’ trips. These values compare with a single value of time of $12/hr. used in the Brisbane Strategic Transport Model.