Travel Time Values Theoretical Framework and Research Outline

Stage I

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An Important Note for the Reader

The research detailed in this report was commissioned by Transit New Zealand, and published by Transfund New Zealand.

Transfund New Zealand is a Crown entity established under the Transit New Zealand Act 1989. Its principal objective is to allocate resources to achieve a safe and efficient roading system. Each year, Transfund invests a portion of its funds on research that contributes to this objective.

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EXECUTIVE SUMMARY

1. The Project
A research project was undertaken in 1996/97 to review issues and practices relating to the valuation of travel time savings in New Zealand and internationally, and to develop an appropriate framework and an outline market research programme for establishing improved valuations of travel time savings in New Zealand. It was intended that these valuations would then be incorporated into procedures for evaluating transport improvement projects in New Zealand.

2. New Zealand and International Practice and Developments
New Zealand historical developments and practice relating to the valuation of travel time savings (VTTS) are described, including in particular the various research work undertaken in New Zealand and the basis of the values used in the Transfund New Zealand Project Evaluation Manual and their strengths and weaknesses.

A summary is presented of VTTS used for road project evaluation in selected countries, principally the UK, USA, Canada and Australia. There are substantial differences between countries (and sometimes even within a country) in the VTTS used for road project evaluations. Different studies have produced a wide range of VTTS estimates, although these tend to converge to a value of 30% to 60% of the wage rate as the average VTTS for non-work travel time.

There is also clear evidence that the (dis)utility associated with travel time varies in different conditions, eg. due to congestion, or on unsealed roads. However, there have been relatively few studies on this issue and no clear consensus on the extent of adjustments that are appropriate. Few countries yet incorporate such adjustments in their VTTS figures used for project evaluation.

3. Theoretical Issues and Framework
The major theoretical issues arising in the valuation of time savings are described and appraised, and an appropriate framework and principles for valuation are developed. Key issues and aspects include: the distinction between opportunity cost and disutility components of time savings; the distinction between behavioural, resource and equity values; the approach to valuing savings in work-related time, incorporating productivity effects and personal utility effects, and having regard to the alternative uses of the time saved; and the treatment of taxation in deriving values for economic evaluation purposes.

4. Market Research Framework
A preferred framework and principles for future market research into VTTS is developed and key issues are addressed. The limitations of relying on revealed preference (RP) data are discussed, and an approach is advocated based primarily on stated preference (SP) data but incorporating RP data relating to travel attributes currently experienced: this is consistent with recent practice internationally. The advantages of deriving valuation functions rather than solely point estimates are discussed. Two case studies of urban mode and route choice are described, and practical issues arising therefrom in deriving valuations are discussed.

5. Market Research Proposals
Within the overall recommended market research framework, outline proposals are developed for market research into VTTS in New Zealand. These proposals are oriented to investigation of

disutility of travel on rural roads in situations with restricted passing opportunities (although they could be applied in large measure to valuations of motorists' time savings in other conditions). The proposals cover survey strategy, sampling basis and sample sizes, experimental design aspects, and the derivation of the required values from the survey results.

ABSTRACT

A research project was undertaken in 1996/97 to review issues and practices relating to the valuation of travel time savings in New Zealand and internationally, and to develop an appropriate framework and an outline market research programme for establishing improved valuations of travel time savings in New Zealand. It was intended that the valuations would then be incorporated into procedures for evaluating transport improvement projects in New Zealand.

The project involved: review of New Zealand and international practice relating to the valuation of travel time savings; appraisal of theoretical issues in the valuation of travel time savings and development of an appropriate analytical framework for valuation; review of market research approaches to obtaining valuations of time savings; and development of an outline research programme for undertaking market research in New Zealand.

1. Introduction

This is the Stage I report of a Transit New Zealand Research Project on 'Travel Time Values'. Savings in travel time represents a major component of the benefits of most road improvement projects. Unit values of travel time savings (VTTS) for use in project evaluation are presented in the Transit Project Evaluation Manual (PEM).

The overall objective of this project was "to establish valuations of savings in travel time and/or improvements in condition of travel".

These valuations were required to cover:

- "The range of trip purposes, e.g. employer's business, commuting, personal business, social/recreational, 'pure' leisure trips.
- "A range of travel 'comfort' conditions, particularly unsealed roads, congested conditions, roads with limited passing opportunities, roads with poor alignment, roads with high 'side friction'."

Stage I of the project was required "to provide a sound theoretical framework within which market research on VTTS in specific conditions can be carried out and applied. In particular, this framework will need to distinguish between:

- "The opportunity cost of time saved (dependent in part on trip purpose); and
- "The 'discomfort' value of time saved.

"Stage I should also outline the requirements for subsequent market research which will provide VTTS estimates within this framework. Subsequent stages of the project would then involve market research to derive the specified VTTS estimates."

Stage I involved three main tasks plus reporting:

- Task 1 - Literature Review. Covers a review of international literature and practice relating to:
  (a) Theoretical framework for use in valuation of travel time savings.
  (b) Market research approaches used for deriving VTTS.
  (c) VTTS practices and values used in different countries.

- Task 2 - Development of Theoretical Framework.
- Task 3 - Development of Market Research Proposals.

1.1 Report Structure

Chapter 2 – Background. Provides an overview of the New Zealand developments and practice relating to VTTS.

Chapter 3 – International Practice. Provides a summary of VTTS used for road project evaluation internationally (covers Task 1c).

Chapter 4 – Development of Theoretical Framework. Covers the range of issues relating to the theory of VTTS and the development of an appropriate analytical framework (covers Task 1a, 2).

Chapter 5 – Development of Market Research Framework. Discusses issues relating to market research to establish VTTS consistent with the theoretical framework (covers Task 1b, part-Task 3).

Chapter 6 – Market Research Proposals. Provides an outline of the proposed market research programme for Stage II (covers part Task 3).

2. Background

This chapter provides an overview of the New Zealand developments and practice relating to VTTS, in particular the various research work undertaken and the basis of the values now used in the Transit Project Evaluation Manual.

2.1 Historical Developments

2.1.1 National Roads Board

The use of social cost-benefits analysis in the evaluation of roading projects in New Zealand goes back at least to the mid-1960s. Values of time saving for road users were recommended by Read (1971) following a review of British and Australian practice. The basic cost/benefit analysis process was brought into use by the Ministry of Works Roading Division via Circular Memoranda 90 and 98. Cox (1983) provided the next comprehensive review of the methodology and practice of VTTS, again based on overseas research. Time values for economic evaluation were established using the marginal productivity of labour approach for working time and based on 25% of the wage rate for non-working time. These values were indexed from year to year as described in Brown Copeland & Co. (1982). This basic method was continued in the successor of CM 98, Roading Division Memorandum RD144, and then into the Technical Recommendation No. 19 on the Economic Appraisal of Road Improvement Projects, known as the "Project Evaluation Manual" or TR9.

2.1.2 Urban Transport Council

In 1986 the Urban Transport Council commissioned research aimed at providing a matrix of travel time values for various trip purposes and travel modes to review and extend the procedures and methods in use. This project resulted in three outputs:

- A review of methodologies and practice;
- A psychological/marketing study of modal choice factors; and
- A summary report.

The project did not achieve its rather ambitious aims but formed the basis for an eventual change in practice under Transit.

2.1.3 Transit New Zealand

On its inception, Transit adopted the National Roads Boards standards and procedural guides, and progressively updated and reviewed them on the basis of changing circumstances, public perceptions and technical knowledge.

In 1989 it sponsored a visit to New Zealand of Dr Ted Miller of the Urban Institute, who prepared a paper and recommendations on VTTS for use in road project evaluation. As his base information, Dr Miller used the earlier UTC reports and further overseas data. The recommendations were not immediately put into effect.

In 1990/91 Transit undertook a review of TR9, including a re-evaluation of the VTTS. This review took account of Dr Miller's analysis and also the UK Value of Time Project and a summary of experience in Australia by Hensher (1989). The background to this review was reported to Transit by Beca Carter Hollings and Ferner (1992). The outcome was the values of time savings incorporated in the Transit New Zealand Project Evaluation Manual (1991 and updates).

In 1992, a substantial research study was undertaken for Transit by consultants Travers Morgan (NZ) Ltd and Beca Carter Hollings Ferner Ltd to "validate and/or refine the travel time values used in the TNZ Project Evaluation Manual 1991", Travers Morgan et al (1997). The study did not undertake any original research, but focused on:

- Reviewing recent international and NZ research on VTTS;
- Identifying the principal areas of uncertainty and weakness in knowledge of VTTS and in the current PEM values; and
- Setting out a research programme and priorities to address the areas of weakness where further research was likely to be most cost-effective.

The study developed draft briefs for eight candidate research projects, provided indicative budgets for these and set out recommended priorities between them.

Among the many points to emerge from the study, in the context of the current project, it was notable that:

- The PEM values made no distinction between different non-work purposes, e.g. commuting, social, holiday/recreational travel. Evidence from elsewhere was that values may differ substantially for different purposes.
- The PEM values made no allowance for differences in travel conditions, e.g. according to comfort or travel time reliability (due to congestion). (The recent PEM update has allowed for differences in discomfort/risk associated with unsealed roads.)

The current research project is, in large measure, the next stage of this 1992 study. It incorporates some of the ideas for further research recommended in that study together with research into issues that have emerged since then.

2.2 Current PEM Values and their Basis

The following paragraphs describe the basis of the present VTTS contained in the Project Evaluation Manual. This discussion has been adapted from Beca Carter Hollings and Ferner (1992). The present values are shown in the Tables 2.1, 2.2 and 2.3 of the PEM (see page 11).

2.2.1 Work Travel

The present calculation of VTTS during working time is based on Cox (1979). The marginal productivity of labour (MPL) approach is used: VTTS is estimated as the gross hourly wage rate plus any employment-related on-costs borne by the employer. The data requirements to calculate the MPL are:

(i) Average hourly gross wage rates, for the range of occupational groups; and

(ii) Information on employment-related on-costs for each occupational group, which include ACC levy, fringe benefits and overheads related to employing an extra person.

In addition, for different evaluation contexts, the proportion of work travellers in the traffic stream, and the distribution of these travellers by occupational group, are required.

In 1978, the main source of data was the latest half-year employment survey (Supplementary Tables to the Labour and Employment Gazette) for gross wages. Additions for employment-related costs were estimated approximately, with the recommendation that these be the subject of more detailed study, which does not seem to have been followed up. The analysis then goes on to suggest a distribution of occupational groups for each vehicle type (urban car occupants, rural car occupants, light commercial vehicle occupants, heavy commercial vehicle occupants), again without any clear substantiation and to be the subject of further study.

The revised values followed the same method of calculation. Information sources were the 1989/90 Household Incomes and Expenditure Survey, the Monthly Abstract of Statistics for wage rate indices, and the Quarterly Survey of Employment figures, February 1990. The index data are projected forward to the July 1991 base date.

There were a number of assumptions in the calculations which it was not possible to check at the time of production of the Project Evaluation Manual. These included the distribution of occupational categories in the working purpose mileage-weighted driving population, particularly for car and light commercial vehicles; and the on-cost rates, for which an attempt had been made to improve on the estimates but which required further work.

There has been no attempt so far in New Zealand to identify the proportion of working travel time devoted to leisure, the proportion of in-travel used for work activity and its relatively productivity, or the utility to the employee of travelling relative to time at the work site. The position which was taken in the preparation of the 1991 Project Evaluation Manual was that overseas empirical research had in general yielded values of work travel time of similar magnitude to the MPL value without any of these adjustments. And so a decision was made to retain the existing method for the time being, in this report.

2.2.2 Non-Work Travel Time

At its December 1991 meeting, the Transit NZ Authority determined that differences in willingness-to-pay for non-work time savings arising from differences in income should not be used for project economic evaluation. However, this did not preclude introducing differences in VTTS based on transport mode, where this was a reflection of modal and passenger characteristics other than income.

2.2.3 Base VTTS for Car Drivers

The base value of non-work travel savings was set for a car driver from an average income household travelling to full-time paid work in free-flowing traffic. The behavioural value adopted, after consideration of the overseas evidence and after correction for indirect taxation, was 40% of the average full-time employed adult hourly income.

The rate of indirect taxation was nominally taken to be 15% (GST of 12.5% plus a small margin for other taxation, such as import duty and excise). A better estimate of the average rate of indirect taxation on goods and services was seen to be required, and a task for future work on the topic.

Adding back this 15% implied a behavioural VTTS of 46% of the average wage rate for car drivers. This was similar as a percentage of gross wage rate to the values recommended by Hensher (1989) for use in Australia (36% private car driver, 61% company car driver) and by MVA et al (1987) in the UK (46%), but less than the value of 60% recommended by Miller (1989).

The value of 40% of the average wage rate was calculated to be $6.13 per hour (1991) which was rounded in the 1991 PEM to $6.10. The same value was adopted for people driving commercial vehicles in non-work time.

2.2.4 Car Passengers

VTTS for car passengers and passengers on other modes of transport were set relative to car drivers. Miller (1989) had recommended a relativity between car passengers and car drivers of 0.69:1.0, based upon Hensher (1989). The logic for adopting a lower VTTS for passengers than drivers was that the disutility of the trip is greater for the driver. However, the question of whether passengers on average have less time constraints than the driver did not appear to have been researched and was considered to be a possible factor.

The VTTS for car passengers recommended for the Project Evaluation Manual was relativity of 0.75:1.0. The reason for this was to maintain a margin between car passengers and bus passengers. While Miller (1989) suggested these be the same, the weight of studies seemed to indicate that VTTS for car passengers would generally be higher than that for urban stage bus passengers, even when income effects were excluded.

2.2.5 Bus Passengers

The recommended VTTS for seated urban stage bus passengers was 25% of the wage rate, a relativity of 0.625:1.0 against car drivers. This relativity was slightly greater than recommended by Miller (1989), and about the same as that recommended in the MVA et al (1987) study, but considerably less than the results of that study which indicated a VTTS for bus passengers about 50% that of car drivers. For express bus services, a higher value is expected, and an equal value to car passenger seems reasonable.

2.2.6 Walking and Waiting for Transport

The PEM does not distinguish between walking for public transport access and walking as the main mode, and does not address waiting time for public transport. The background working paper did, however, consider this issue, recommending a single value for walking and waiting time for public transport access equal to the 1.5 times the VTTS for car drivers. This was a similar relativity to the values recommended by Miller (1989), and equated to 2.4 times the recommended value for seated bus passengers. This value was also recommended for walking and cycling as main modes, although the empirical research to support this was recognised to be inadequate.

2.2.7 Trip Purpose

No compelling evidence was recognised to differentiate VTTS between different non-working trip purposes, although Hensher (1989) was noted as an exception (more investigation of this matter is thought to be required, in particular, the grounds for differentiating between recreational travel and other non-work trip purposes).

2.2.8 Modifying Factors for Congestion and Reliability

There was found to be good evidence that time savings in congested traffic were valued more than in free-flowing conditions, although the degree to which this was contributed to by uncertainty and how much by driver stress and frustration from the road conditions was less clear.

It was seen to be desirable that the benefit of increased reliability of transport service be recognised in project evaluation, so that service improvements that achieved such improvements be recognised, even though this may not result in overall time saving.

Miller (1989) had recommended a factor of 1.5 between congested and free flowing traffic while the MVA studies suggested a factor of 1.4 from the situations studied and maybe higher under more congested conditions.

Two possibilities for including congestion and reliability effects in evaluation were under active consideration at the time of production of the original Project Evaluation Manual, either to vary the VTTS with traffic level of service (A to E), or to apply a higher VTTS to stopped vehicle time. Neither was implemented because this somewhat radical departure from current practice needed further consideration.

2.2.9 Modifying Factors for Standing Passengers

While the evidence on which to suggest modifying factors for levels of in-vehicle comfort was originally found to be limited, a main discriminating factor was suggested to be whether passengers had to sit or stand. The base values assumed fully seated passengers. Miller (1989), on the basis of Algers and Widlert (1985), recommended a VTTS of 250% of the wage rate, or six times his base passenger values, for standing passengers. This very high value was not applied in the PEM; instead a modifying factor for having to stand of 2.0 times the seated in-vehicle time value, that is 50% of the wage rate for an urban bus, was recommended.

2.2.10 Modifying Factors for Unsealed Roads

A 1992 Transit research project found strong evidence of travellers' willingness-to-pay to travel on sealed rather than unsealed roads, reflecting the greater comfort and lower perceived risks associated with sealed roads (Travers Morgan et al, 1994). As a result of this research, in the PEM update, an additional comfort benefit of 16¢/vehicle kilometre was introduced for road sealing projects.

2.2.11 Modifying Factors for Person Type

The lower VTTS for students and retired persons allowed in the new UK procedures were recommended for inclusion in New Zealand practice. However, this was another refinement which did not find its way into the 1991 issue of the Project Evaluation Manual.

2.2.12 Freight Time Savings

The significance of a value for freight time savings in comparison with the value of time for the heavy vehicle carrying the freight had, in the past, been judged to be very small. However, this was an issue which was questioned from time to time, and was considered in the preparation of the Project Evaluation Manual. Again, the conclusion was reached that this effect was likely to be very small and no allowance was in fact made in the 1991 Manual, although it was suggested that the matter receive some further study.

Table 2.1 Base Values for vehicle occupant time in $/hour (July 1994) (PEM Table 3.1)

Vehicle Occupant	Work Travel Purpose	Non-Work Travel Purpose
Car, Motorcycle Driver	19.80	6.50
Car, Motorcycle Passenger	19.80	4.90
Light Commercial Driver	17.90	6.50
Light Commercial Passenger	17.90	4.90
Medium Commercial Driver	14.70	6.50
Medium Commercial Passenger	14.70	4.90
Heavy Commercial Driver	14.70	6.50
Heavy Commercial Passenger	14.70	4.90
Seated Bus Passengers	19.80	4.10
Standing Bus Passengers	19.80	8.20
Pedestrian and Cyclist	19.80	9.80

Table 2.2 Base values for vehicle and freight time in $/hour (July 1994). (PEM Table A3.2)

Vehicle Type	Vehicle and Freight Time
Passenger car	0.40
Light Commercial Vehicle	1.50
Medium Commercial Vehicle	5.20
Heavy Commercial Vehicle I	14.70
Heavy Commercial Vehicle II	24.20
Bus	0.00

Table 2.3 Travel time cost for standard traffic mixes: occupant time, vehicle time and freight time combined. (PEM Table A3.3)

Road Type and Time Period	$/h 1 July 1994
URBAN ARTERIAL:	
Morning Commuter Peak	13.4
Daytime Inter-Peak	16.6
Afternoon Commuter Peak	12.8
Evening/Night-time	13.9
Weekday All Periods	15.1
Weekend/Holiday	12.4
All Periods	14.4
URBAN INDUSTRIAL:	
Weekday	18.4
Weekend/Holiday	15.2
All Periods	17.6
URBAN OTHER:	
Weekday	14.2
Weekend/Holiday	11.7
All Periods	13.7
RURAL STRATEGIC:	
Weekday	22.2
Weekend/Holiday	16.0
All Periods	20.1
RURAL OTHER:	
Weekday	21.0
Weekend/Holiday	15.3
All Periods	19.3

3. International Practice

This chapter provides a summary of VTTS used for road project evaluation internationally, with an emphasis on English-speaking developed countries for which values are relatively well-documented and accessible, i.e. principally United Kingdom, United States, Canada and Australia.

The principal source of this information is research undertaken by Bill Waters in 1992-93 (Waters 1992 and 1994), and this has been supplemented by a number of more recent papers. While the data in this principal source is now around five years old, no comprehensive update appears to be available. However, papers from a recent PTRC (UK) conference may provide a more comprehensive update.

The values obtained by Waters were generally updated to 1990 Australian dollar values. For consistency, this chapter generally quotes values in these terms, but indicates approximate factors to adjust to 1997 New Zealand dollars.

3.1 United Kingdom

Probably the most ambitious review of VTTS was that carried out in the UK, MVA Consultancy et al (1987); see also Sharp (1988). They reviewed the theory of travel time valuation, reviewed existing empirical evidence, and conducted a number of additional empirical studies. The most important conclusion was the decision to increase the base non-work VTTS from 25% to 40% of the wage. The figures adopted officially by the UK government for transport project evaluation are as follows, Sharp (1988):

	pence/hour (1985)	AUS$/hour (1) (1990)
Standard appraisal value	153.2	4.59
People of working age	180.5	5.42
Retired people	121.0	3.63
All adults	175.8	5.27
Children less than 16	45.2	1.35

Note (1) Factor 1.46 approx to convert to NZ$1997

The "standard appraisal value" is the weighted average of the remaining categories. As with previous UK practice, the VTTS is adjusted for waiting, walking and riding time. The UK government explicitly rejected incorporating an adjustment for income despite evidence of a link between incomes and VTTS.

3.2 United States

The most notable review of VTTS in the United States was in connection with the update and revision to the original American Association of State Highway and Transportation Officials (AASHTO) manual (1977). This is the most widely used guidebook for highway and transit project evaluation in North America. While this update was not yet complete (in 1993), the most likely recommendations are those in TTI (1990) which reviews a number of VTTS studies for different valuation approaches. Their recommended VTTS is about 80% of the wage rate. They do not distinguish between work and non-work time. Table 3.1 lists the suggested AASHTO update figures, converted to AUS$.

Miller (1989) has also carried out various reviews of VTTS and made recommendations to the US Federal Highway Administration. His recommendation of 60% of the wage for non-work VTTS has been adopted by FHWA.

The individual US states vary immensely in their procedures for highway evaluation. Cost benefit analysis (CBA) is employed by a few states; many have adopted various ad hoc criteria, normally defined in terms of highway sufficiency ratings or other technical criteria. Most states which do carry out CBA studies rely on updated AASHTO figures.

Table 3.1 Recommended VTTS for the New AASHTO Guide

Vehicle Type	Value of Time AUS$ per Vehicle Hour [(a)]
Passenger Cars	16.23 [(b)]
Buses	162.72 [(c)]
Trucks	
Single-unit, 2-axle, 4-tire	20.89
Other Single-unit	24.94
Semi Combinations, 4 or less axles	31.10
All others, 5 or more axles	34.52

Source: TTI (1990)

(a) All figures are converted to AUS $1990 after conversion to $CDN and indexed up. Apply a further factor of 1.46 (approx) to convert to NZ$1997.

(b) Assuming 1.3 persons per vehicle

(c) Assuming 10 passengers per vehicle.

3.3 Canada

Lawson (1989) reviewed the VTTS literature and practices in several countries for Transport Canada. Largely on the basis of Lawson's review, Transport Canada (1990) recommended 50% of the wage for the valuation of non-work time savings. Notable was Transport Canada's adoption of a uniform non-work VTTS for all modes, including air travel. This reflected a rejection of varying time values by income levels, which largely explains the differences in VTTS found in different modes. The not-yet-official figures (as in 1993) are shown in Table 3.2.

British Columbia completed a review of VTTS (Waters 1992). Although a base VTTS of 50% of the wage was recommended, British Columbia adopted 40% of the wage as the base VTTS, and incorporated various adjustments for age, travel conditions (degree of congestion) but no adjustment for income levels. These are indicated in Table 3.3.

A few other provinces have conducted CBA studies, although none of them rely on CBA on a consistent basis. British Columbia is the most active in reviewing the applicability of CBA to highway evaluation. Table 3.4 reports on the VTTS figures for five other provinces.

Table 3.2: Transport Canada's Proposed Values of Passenger Time

Mode	$/Hour 1986 Base Year - Converted to 1990 AUS $ Dollars		
	Business Travel	Non-Business Travel	All Travel
Air	34.45	6.59	23.11
Auto	22.03	6.59	9.39
Bus	22.03	6.59	8.64
Highway	22.03	6.59	9.29
Rail	22.03	6.59	10.69
All non-Air	22.03	6.59	9.39
All Modes	**25.38**	**6.59**	**10.04**

Source: Transport Canada (1990) p.iii.
Notes (1): Apply a factor of 1.46 (approx) to convert to NZ$1997.

Table 3.3: British Columbia's Value of Travel Time Savings (AUS$1990) (1) (2)

Category	Work	Non-Work
Passenger cars & light trucks:		
Driver (Adult)	$19.02	$6.34
Driver (Retired)		$4.44
Passenger (Adult)	$19.02	$4.44
Passenger (Retired)		$3.20
Passenger (under 16)		$2.69
Bus:		
Driver	$32.61	
Passenger (Adult)		$4.44
Passenger (Retired)		$3.20
Passenger (under 16)		$2.69
2-Axle Trucks:		
Driver	$29.45	$8.16
5-Axle Trucks:		
Driver	$32.43	$9.18

Note: (1) Apply a factor of 1.46 (approx) to convert to NZ$1997
(2) The non-work VTTS is higher for waiting time as well as travel time in highly congested conditions.

Table 3.4: Summary of Value of Time Figures: Canadian Provincial Highway & Transportation Departments (1990 AUS$) (1)

Alberta	$ 6.48/hour (Non-Work trips) $14.04/hour (Commuting) $25.38/hour (Trucks)
Manitoba	$ 6.48/hour (Autos)
Ontario (2)	$11.96/hour (Work Trips) $ 3.19/hour (Commuting) $49.95/hour (Trucks)
Quebec	$10.69/hour (Auto - Work Related) $ 2.24/hour (Auto - Non-Work Related) $15.24/hour (Truck - 2 Axle) $16.45/hour (Truck - 5 Axle)

Source: Waters (1992)
(1) Figures have been converted to AUS$ 1990 unless otherwise noted. Apply a further factor of 1.46 (approx) to convert to NZ$1977
(2) Ontario figures for 1983, converted to AUS$ and indexed to 1990.

3.4 Australia

Hensher's 1987-88 work brought together Australian research on VTTS and put forward a unified set of both behavioural and resource VTTS, suitable for use in traffic modelling and evaluation in urban and rural situations (Hensher 1989). The 1987 values recommended by Hensher are shown in Table 3.5.

These values were adopted by the National Association of Australian State Road Authorities (NAASRA) as its recommended values in 1989. While it was hoped that these same values would be adopted by all Australian states, this has not happened in practice. However, the recommended values have acted as a catalyst for each state to reconsider the values it adopts, and the recommendations have been loosely followed in most states.

The Table 5 values are based on an average indirect tax rate of 14% (calculated as the ratio of indirect taxes less subsidies to GDP at market prices). For updating the working time estimates, allowance will need to be made for changes in company tax rates since 1987/88.

Table 3.5 Australian Values of Travel Time Savings per Person – Summary (AUS$1987) (1)

I. Non-Work	Behavioural In Vehicle	Behavioural Out of Vehicle	Resource In Vehicle	Resource Out of Vehicle
Urban/Local non-urban				
Commuter by private car	4.65	12.50	4.08	10.96
Commuter by company car	7.87	21.20	6.90	18.60 *
Social/Recreational as driver or passenger ††	2.90	7.80	2.54	6.84 *
Commuter by private car as passenger	3.25	9.40	2.85	8.25
Commuter train	2.43 **	12.98 **	2.13 **	11.39 **
Commuter bus	4.00 **	7.97 **	3.51 **	6.99 **
Long Distance:				
Non-business	6.52	14.00 *	5.72	12.28 *

II. Work (i.e. trips made in the course of work)	Employer Behavioural Value	Resource Value
Urban (car) travel as part of work	10.10 —	20.20 —
Long distance (air, car)	12.50-25.00 —	21.40-25.00 —

III. Non-Work Equity Values † (Assuming average annual gross income of $25,640, with 100 annual hours worked)	
In-vehicle time:	$4.18
Out-of-vehicle time:	$11.98

Source: Hensher (1989)

Notes:

(1) Apply a factor of 1.8 (approx) to convert to NZ$1997

* Indicates that the value was not derived from an empirical model, but from other purposes which are assumed to reflect the relative utility of alternative components of time.

** Is an update of the 1982 values. (Income has increased by a factor of 1.35 since 1982).

†† Indicates that relating this trip purpose value to income is problematic because a large number of trips are by individuals who do not go to work. One could use the mean income of the employed sub-group.

† The reported equity values are simple averages of the six non-work values. This approach assumes that each individual has one market vote of equal power so that one group is given market power by their ability to pay.

3.5 West European Countries

Reviews of VTTS have been conducted in several European countries (other than UK). Table 3.6 summarises the figures from selected countries.

3.5.1 Germany

Lawson (1989) reports values of time for evaluating infrastructure investments for the Federal Republic of Germany. They only distinguish work and non-work time, with a substantial relative difference.

3.5.2 Finland

Lawson (1989) also reports the values of time for road investment appraisal in Finland. The value for work trips is a gross wage including a 57% mark-up to reflect 'social security costs.' For commuting and personal business, the value of time is 35% of the gross wage, and the value of time for leisure travel is assumed to be 20% of the wage.

Table 3.6: Values of Travel Time Savings for Selected European Countries (1)

Federal Republic of Germany	**DM/hr (1985)**		**AUS$/hr (1990)**
working time	12.67		9.00
non-work time	2.11		1.49
Finland	**FIM/hr (1988)**		**AUS$/hr (1990)**
work trips	64.40		21.72
commuting	14.40		4.86
leisure	8.20		2.77
weighted average *	16.10		5.43
(* Weights are proportion of vehicle kilometres 17%, 39%, 44% respectively). Source: Lawson, 1989, p.30			
Norway	**Kr (1988)**		**AUS$/hr (1990)**
only one value of time reported	50 kr		11.30
Sweden	**SEK/hr**		**AUS$/hr (1990)**
private traffic			
work trips			
state highways	135		32.78
municipal roads	121		29.38
non-work trips			
state highways	25		6.07
municipal roads	21		5.10
Netherlands (1990 AUS$/person hr.)	**commuting time**	**business time**	**other**
base value (low income)	3.92	5.09	4.14
avg. value across sample *	7.11	11.09	4.53
(* adjustments include for income, household composition, occupation, age, sex, amount of personal free time, trip purpose, travel mode and journey conditions.)			

Sources: VTTS for Germany, Finland, Norway and Sweden are from personal communications reported in Lawson, 1989. Conversions to AUS$ done by Waters (1993). Standard value per vehicle hour for Sweden is from Swedish National Road Administration (1986) Calculation Guide, p.13 as cited in Lawson, 1989.
Figures for the Netherlands reported in Bates and Glaister, 1990.

Note: (1) Apply factor 1.46 (approx) to convert from AUS$1990 to NZ$1997.

3.5.3 Norway

Lawson (1989) reports a value of time for Norway of 50Kr per hour in 1988, or AUS$11.30/hr in 1992. No further breakdown was reported.

3.5.4 Sweden

The value of time for Swedish road investment appraisal is published by the Swedish Road Administration (cited in Lawson 1989). The values for work trips are relatively high. The VTTS differ by type of highway.

3.5.5 Netherlands

Bates and Glaister (1990) summarise the VTTS studies for the Netherlands. The Netherlands Government sponsored a major study on value of time, carried out by the Hague Consulting Group (1990). The study includes breakdowns of time values by trip purpose, income level and a number of other characteristics including travel conditions, age, and amount of free time. The VTTS while working ranges from AUS$5.09 to AUS$11.09; the highest income class has more than double the value of time of the next highest class. Values for commuting time and other trip purposes are about 70% to 80% of the work time value (except for highest income class). The base and average values (1990 AUS$) are reported in Table 3.6. The VTTS may be adjusted for a variety of factors including household composition, occupation, age etc.

3.6 Treatment of Disutility of Travel Conditions

The VTTS figures quoted in the previous sections essentially reflect the opportunity cost of time spent travelling, on the basis that the personal utility (comfort, convenience etc.) of the time spent travelling is similar to that involved in the alternative use of the time. In addition, in certain conditions there may be a significant disutility component associated with the time spent travelling, e.g. if spent in crowded conditions. This disutility issue is of particular interest to Transit in its review of VTTS and hence this section highlights international practice in the valuation of such disutility in different travel conditions.

3.6.1 Congestion and Reliability Factors

There are two distinct disutility effects which are often not separated in practice: the extra stress associated with travelling in congested conditions; and the uncertainty or reliability of travel times (which are often associated with congestion).

British Columbia applies the following factors to non-work VTTS for congested conditions:

Level of Service D	Factor 1.33
Level of Service E	Factor 1.67
Level of Service F	Factor 2.00
Stoppages of any kind	Factor 2.00.

United Kingdom studies indicate that VTTS in congested conditions is 30-50% higher than in free-flow condition (MVA et al 1987; Miller 1989). Miller examined a number of studies and recommended a 60% increase in VTTS for drivers and passengers in congested conditions.

A pilot market research survey found that motorists rated travel in slow-moving city traffic as three times more annoying than travel on a regular busy highway; which in turn they rated three times more annoying than travel on non-busy highways (Waters and Evans 1992). However this is not to say that the VTTS will vary in the same proportions, as the 'annoyance' factor is only one component in the valuation of time savings.

The major Netherlands VTTS project found that unit values for motorway travel increased by up to 60% as average speeds fell from above 110km/hr to below 90km/hr. However, contra to expectations, VTTS in urban conditions were similar to those in uncongested motorway conditions, Bradley and Gunn (1990).

A review of empirical evidence suggested that 'average' VTTS figures might be reduced by 15% for uncongested conditions and increased by 15% for very congested conditions, Bates and Glaister (1990).

3.6.2 Comfort Factors

There is limited evidence available on travellers' willingness-to-pay to improve the physical comfort of their travel (additional to effects related to congestion).

For car travel, the recent work for Transit New Zealand on willingness-to-pay to avoid travelling on unsealed roads was a pioneer on this topic (Travers Morgan et al 1994).

For public transport travel, there has been more research. Most studies have indicated that VTTS for standing passengers is around twice that for seated passengers, while VTTS in very crowded conditions may be much higher. There are also differences between public transport modes, associated with ride quality etc. – typically VTTS for rail-based services is 10% – 25% lower than for on-street bus services.

3.7 Summary of International Practice

Both the empirical and theoretical values of VTTS used in practice differ considerably between countries and among agencies carrying out road project evaluation. It may not be surprising that VTTS might differ among countries, because of cultural and income differences. On the other hand, all of these studies and practices are from relatively wealthy countries where car travel is a common characteristic of life. Regardless, there appears to be comparable variation in VTTS employed within countries as compared across countries. Table 3.7 summarises the VTTS for work and non-work travel for several countries and jurisdictions. These figures should be regarded as approximate; in some cases they are based on different year base figures which have been updated, while exchange rates differ over time. Further, many countries add various adjustments to a base VTTS depending on income, travel conditions, etc. Nonetheless, Table 7 indicates substantial variations in the VTTS being employed for highway project evaluation. Under present evaluation frameworks in different regions and departments, a similar project could be rated quite differently because of differences in assumed VTTS.

Unfortunately, the empirical evidence does not offer a clear guide to the appropriate value for VTTS. Different studies, using different methodologies at different places and times, for different travel conditions, have produced a wide range of VTTS estimates. These diverse estimates tend to converge to a value of 30% – 60% of the wage rate as the average VTTS for non-work travel time.

There is clear evidence that the (dis)utility associated with travel time varies in different conditions, e.g. due to congestion, or on unsealed roads. However, there have been relatively few studies on this issue and no clear consensus on the extent of adjustments that are appropriate.

Few countries yet incorporate such adjustments in their VTTS figures used for project evaluation.

Table 3.7: Summary Comparison of Values of Travel Time Used for Road Project Evaluation in Various Countries and Government Agencies

Country/Jurisdiction	$/vehicle hr (non-work time)	$/person hr (non-work time)	$/person hr (work time)
United States			
AASHTO (used by several states)	18.93	14.56	14.56
California	9.22	--	--
Florida	20.34	15.65	--
New York		5.75	--
Canada			
Transport Canada		6.59	22.03
Ontario		3.19	11.96
Quebec		2.24	10.69
Alberta		6.48	14.04
British Columbia		6.34	19.02
Europe			
United Kingdom		5.42	--
Germany		1.49	9.00
Finland		4.86	21.72
Holland (base figure)		3.92	5.09
(avg. adjusted)		7.11	11.09
Sweden (rural)		6.07	32.78
Australia			
New South Wales (rural)		7.12	26.89
South Australia (rural)		3.51	13.29

Rural area figures where distinguished in approximate 1990 AUS$[1]
Note: (1) Apply factor of 1.46 (approx) to convert from AUS$1990 to NZ$1997.

4. Development of Theoretical Framework

4.1 Time as a Resource

Time is an important input in consumption (e.g. leisure) and production (e.g. work) activities. The use of time involves an opportunity cost which must be valued. Early theoretical studies of time use Becker (1965) assumed that time was a homogeneous scarce resource used in the production of market goods and services (i.e. work activity), as well as in the 'production' of household commodities (i.e. consumption activities). Importantly, in Becker's model, time was not consumed directly by an individual, but regarded as a factor of production or an intermediate good. This is different to the assumption made in Section 5.2 where we allow time as a factor input to be a source of (indirect) utility per se.

The use of time in any consumption activity is described by a Household Production Function (HPF) which can be presented in money units (e.g. income earned from work activity), in time units (e.g. length of working hours or leisure hours), or in other units such as distance travelled or the number of trips per unit of time. It is this *activity* (or production) output which enters directly into the individual's utility function rather than the factor inputs. As a homogenous resource, its value is also unique in all activities, and is referred to as the value of time as a resource or the Shadow Price of Time.

This is a useful starting position, but one of very limited value in transport studies. Although it recognises that time is a resource, it imposes a very strong assumption that the value of that resource time is independent of the activity which utilises that time.

4.2 The Heterogeneity of Time

There are conceptual difficulties with an approach which treats time as a homogeneous resource. To highlight the problem, let us assume that the output of the activity 'travelling to work' is the number of trips per unit of time. Can a trip by car be considered as physically the same output as a trip by bus or train? If the answer is yes, then we are neglecting any quality differences between different modal trips (i.e. time is homogenous). If the answer is no, how are we to incorporate quality differences, or recognise the heterogeneity of time.

Since an individual cannot 'easily' adjust the level of output to allow for quality differences, we can redefine each modal trip as a commodity in its own right. Thus production of a car trip cannot be described by some HPF as production of a public transport trip. The activity 'travelling to work' is now replaced by a series of different activities, each related to a separate exogenously specified modal technology. Becker's concept of activity (output) is of limited empirical value. The fundamental limitation is described by Pollak and Wachter (1975, 270-71): "We object to the implied but crucial assumption [underlying a HPF approach] that time spent cooking and time spent cleaning are 'neutral' from the standpoint of a household and that only the 'outputs' of these production processes enter the household's utility function."

Thus we prefer to assume that activity output cannot be defined independently of the specific circumstances under which time is spent. The alternative approach is to select *activity inputs* (i.e. market goods and household time) as the only valid and observable commodities which can then enter directly into the individual's (household's) utility function.

The distinction between time as a commodity and time as a resource, introduced by DeSerpa (1971), is fundamental to the understanding of the complex components of the value of travel time savings. Time is a commodity because it can generate utility directly to the individual when 'consumed' in specific activities. But at the same time, it also acts as a means for the consumption of market goods and services, just as money is a means for the purchasing (and hence consumption) of these goods and services. In its role as a commodity, time in a specific activity i is not the same commodity as time in another activity j.

The individual's utility function can be expressed as:

$$U = U(x_1, T_1; x_2, T_2, ..., x_n, T_n) \quad (1)$$

where $\{T_1, ..., T_n\}$ is the time spent in activities 1 to n; and $\{x_1, ..., x_n\}$ is market goods and services consumed jointly with time in the activities.

In DeSerpa's model, 'commodities' denote market goods and/or services and/or time inputs into activities. Activity is defined in terms of inputs. In its role as a means for the consumption of goods and services x_i's, time is subjected to a resource constraint T_o):

$$\sum_{i=1}^{n} T_i \leq T_0 \quad (2)$$

Similarly, the means for purchasing the x_i's are also subjected to a resource constraint (M):

$$\sum_{i=1}^{n} p_i x_i \leq M \quad (3)$$

where p_i is the unit price of a good or service. Time consumption in many activities is not entirely a matter of an individual's own free will. So in addition to the time-resource constraint (2), there are time consumption constraints:

$$T_i \geq a_i x_i \text{ ; } i=1, ..., n \quad (4)$$

These constraints include technological and institutional constraints. a_i is a technological coefficient unique to the ith alternative defined as the ratio of the (minimum) time to cost. Examples of technological constraints are the available set of modes which have limits on the combinations of travel times and costs which can be offered. An example of an institutional constraint is the legal speed limit. The application of microeconomic theory recognises these limits imposed on a solution to the value of transferring time. It may be shown that:

$$\frac{\partial U/\partial T_i}{\partial U/\partial M} = \frac{\mu - \kappa_i}{\lambda} \quad (5)$$

which is the marginal rate of substitution between commodity-time, T_i, and the numeraire good at constant (maximum) utility level. It is referred to as *value of time as a commodity in activity* i. μ is the marginal utility of money, λ is the marginal utility of time as a homogeneous resource, and κ is the marginal utility due to relaxing the technological constraint for alternative *i*. The activity constraint which establishes the difference between $\frac{\mu}{\lambda}$ and $\frac{\mu - \kappa_i}{\lambda}$ is binding, i.e. if $T_i = a_i x_i$, and hence $\kappa_i \neq 0$. This difference is referred to by DeSerpa as the value of saving time consuming, x_i, or value of time-saving in activity, I, ($VOTS_i$).

If an individual is constrained to spend at least a minimum amount of time ($a_i x_i$) in this activity, and assuming that this minimum level exceeds the level at which the individual derives the optimal value from time consumption, then the marginal value obtained from time is less than its shadow-price (optimal value). The difference is the loss in value (utility) of time spent in this activity. This is value of time savings. If the individual could save this marginal unit of time, he could potentially save this value from being lost. The actual value of the saving however depends on where the unit of saved time is spent. If it is spent in a leisure activity (defined as one which has a non-binding time consumption constraint), then actual saving = potential saving. If it is spent in an 'intermediate activity' (defined as one which has a binding time consumption constraint such as travel), then the actual saving in value would be less than the potential saving (κ_i/μ).

4.3 Opportunity Cost and Disutility Components

The value of travel time savings has been shown to have two components: an opportunity cost component reflecting the economic value of the resources associated with the 'consumption' of time (referred to as the shadow price of time), and a relative (dis)utility component reflecting the alternative circumstances under which a unit of time is 'consumed'.

For example, 10 minutes spent waiting for a bus engenders greater disutility to a traveller than 10 minutes travelling in a bus or a car. The amount of time resource is the same and hence the opportunity cost is equivalent. This important distinction, linked back to the theoretical model initially developed by DeSerpa (1971), has been translated into an appropriate empirical model of consumer (or traveller) behaviour choice by Truong and Hensher (1985, 1987) and Bates (1987) of the form:

$$V_i = \alpha_i - \lambda C_i - \kappa_i T_i \qquad (6)$$

where V_i represents the (indirect) utility expression associated with alternative i, α_i is the mean of the unobserved influences on choice of alternative *i*, C_i is the monetary cost of using alternative *i*, and T_i is the travel time associated with alternative *i*. Importantly the parameter λ associated with money cost is independent of alternative *i*, in contrast the parameter estimate κ_i associated with travel time is dependent on the particular alternative. The latter reflects the different circumstances under which travel time is consumed in the use of each alternative. The value of travel time savings is given by κ_i/λ. If the shadow price of time (time being a scarce resource) and its actual value in a specific activity are the same, then κ_i/λ equals μ/λ. That is, the relative disutility of travel time is zero.

The important implication of this derivation of an empirical indirect utility expression (6) from economic theory as applied in a mode choice context is that it is not possible to identify the resource value of travel time unless we can assume that the relative disutility associated with spending time on alternative modes of transport is zero. What we can measure is the value of transferring time from activity i to some non-travel activity. To be able to separate out the resource price of time from the value of saving time, we would need to know a priori the resource price of time. Treating the differences in mode-specific values of transferring time (due to different parameter estimates for each mode) as zero (i.e. by constraining the parameters to be identical across the modes) is not a mechanism for obtaining a resource value, without imposing the strong assumption that the marginal (dis)utility of time spent travelling is zero, in contrast to it being constant for all modal alternatives.

The adjustments to these behavioural values, derived from empirical mode choice models to obtain appropriate values of the cost to society of time resources consumed in travel is controversial in the light of the theoretical argument. In section 4.4 we identify the practice of modifying the empirical behavioural values to represent an appropriate set of values of travel time savings to represent the cost to society of time resources consumed. Assuming that the opportunity cost associated with the time resource is suitably measured by the (competitive) market price, and that market prices are often distorted true resource (shadow) prices due to the presence of a number of externalities, practice has involved some limited adjustments to allow for distortions created by taxation. Other distortions have not been considered (such as regulations, price capping etc.), with the consequence that our best estimates of the social value of travel time savings derived from utility-maximising discrete choice models approximates the behavioural values of travel time savings.

We now turn to another paradigm for valuation which is appealing in the context of trade-offs between travel and work.

4.4 The Production Cost Approach

Traditionally, an alternative to the behavioural approach to travel time savings valuation in the work-travel context was the adoption of marginal productivity theory which states that an employer can be expected to employ labour up to the point at which the total costs of employment equate with the value of production. The value of working travel time savings is then estimated as equal to the gross wage rate (including on-costs) plus a marginal wage increment to allow for any savings in overheads associated with an employee travelling in contrast to spending the equivalent time in the office. This approach makes questionable assumptions about the transfer of travel time to other purposes. It neglects possible productive use of in-travel time (particularly at the marginal rate), and ignores the utility to the employee of time spent at work compared to travelling.

Hensher (1977) suggested an alternative approach to deriving the value of travel time savings for work-related travel. The approach recognises a number of components of opportunity cost and relative disutility. The approach has been applied in the context of business air travel in Australia, and commercial car travel in Sweden, the Netherlands and the United Kingdom. There are four main elements of the formula - a productivity effect, a relative disutility cost, a loss of leisure time and any compensation transfer between employer and employee.

These components are combined into the following formula:

$$VTTS = (1 - r - pq)*MP + \frac{1-r}{1-t}*VW + \frac{r}{1-t}*VL + MPF \quad (7)$$

where

r = proportion of travel time saved which is used for leisure.

p = proportion of travel time saved at the expense of work done while travelling.
q = relative productivity of work done while travelling compared with the equivalent time in the office.
MP = the marginal product of labour.
VL = the value to the employee of leisure relative to travel time.
VW = the value to the employee of work time while in the office relative to travel time.
MPF = the value of extra output generated due to reduced fatigue.
t = employee's personal tax rate, the inflation of rVL and (1-r)VW reflecting compensation. An employer has to compensate an employee for travel, in terms of travel time savings rather than increased income, to allow for the fact that increases in the employee's utility are not subject to tax.

VL is the traditional behavioural value of travel time savings associated with trading travel time with leisure (i.e. non-work) time. The traditional category of business/commercial car travel is usually reserved for 'travel as part of work'. However a significant amount of work-related travel involves activities such as driving to the airport or a client's office. Since a high percentage of the travel time associated with the latter activity occurs outside of normal working hours (i.e. the person would not be travelling at this time during the normal period of work expected by the employer) and is not compensated in any manner by the employer, there is a leisure time trade-off being made. The value of travel time savings thus can be expected to be lower than the average gross wage rate, reflecting the mix of both employer time and non-work time.

Unpublished studies undertaken by the Hague Consulting Group in 1994 in Holland, the United Kingdom and Sweden, using Hensher's model (Hensher 1977) provide supporting evidence for business values of travel time savings being significantly less than the gross wage rate. Overall, the value to the employer of savings in car travel times in the UK are approximately 50% of the average gross wage rate, 61% in the Netherlands and 32% in Sweden. The lower Swedish value is attributable to greater productivity in the car (especially due to high availability of mobile phones).

4.5 Behavioural, Resource and Equity Values

The values of travel time savings derived from travel choice models are *behavioural* values. They tell us how much an individual traveller is willing to pay to save a unit of travel time, ceteris paribus. Such values are appropriate in demand prediction where there is an interest in using a generalised cost or generalised time variable. Combining of travel cost and travel time into one service indicator is promoted where there is high correlation between the component attributes, which is most likely to occur where there is no or limited congestion and/or where levels of service are extracted from a network which tends to reduce the variability in attribute levels substantially.

When the time savings values are applied to a change in the level of economic resources, a willingness to pay (WTP) measure does not always represent the resource implications of the savings or loss of travel time, as demonstrated in the theoretical framework above. Resource values are required to convert the predicted change in travel time into monetary units. The presence of direct and indirect taxation has to be considered in the establishment of resource values of travel time savings. Alternative approaches to correcting for the resource effect have been suggested in the literature.

To understand the complication of taxation - direct and indirect - we have to be clear on the meaning of "resources consumed" in the process of "consuming" travel time. The process of consumption entails a transfer of time from one activity to another activity and as such is not time "saved" per se. This is the basis for preference for the phrase "value of transferring time" originally proposed by Hensher and Truong (1983) and Truong and Hensher (1985) and adopted by Bates and Glaister (1990) in a recent review of the literature undertaken for the World Bank.

Economists talk of valuing goods and services at their resource costs on the grounds that they most clearly represent the real cost to the community in terms of resources embodied in their production, and hence indirect taxes and subsidies are excluded. While this may be an unambiguously valid position for estimating changes in national income aggregates, it is arguably an incorrect principle for sectoral cost-benefit evaluations. The cost to the community of a resource to be used in a sectoral project is determined by the *value* it creates in the use from which it is to be moved (i.e. its opportunity cost). This is the essence of shadow pricing of a resource where we distinguish the marginal production cost of new resources and the market price for existing resources. Thus, if a resource is moved from the production of some good subject to a 100% tax for example, its cost to the project must be valued as equal to the price, which is twice the resource cost. The distinction between "cost" and "value" is fundamental to an appreciation of this argument.

We tend to assume (implicitly) that our resources already exist in that they are being utilised elsewhere; thus market price is the appropriate basis of identifying the opportunity cost of a resource. The theoretical model driving the pure definition assumes a perfectly competitive market; in reality however there are distortions such as minimum wages and maximum hours worked. Thus the observed market price may indeed be a distorted measure of value, an over- or under-estimate due to the presence of institutional constraints. In a sense this is a form of negative externality in a competitive market. So even though the savings in resources can be observed via market prices, those resources may actually be worth less in a competitive market. That is, institutional constraints have artificially over-priced the real value of a resource.

There is a view that for non-working time the behavioural value of time savings should be the same for all modes/routes and trip purposes. The resulting equity value is consistent with the position that the scarce investment dollar should not be directed towards projects which are more likely to benefit individual travellers with a higher willingness to pay simply because they have a greater ability to pay. This argument rests on the proposition that the value of travel time savings is a function of personal income. Although the empirical evidence on the relationship between VTTS and personal income is ambiguous, despite its theoretical appeal, equity behavioural values of travel time savings can be derived from the behavioural values for non-working time. If equity values are used, then the resource value for non-working time should be derived from this equity value.

4.6 The Treatment of Taxation

For shadow pricing, the tax treatment varies depending on whether additional income-earning (i.e. productive) time ensues; or whether the transfer is into leisure time which is not subject to direct taxation because it is not income earning. One can expect quite different shadow prices (i.e. true resource values) because a lot of what we have traditionally called a transfer from travel to productive income-earning work time is in fact a transfer to non-productive leisure time.

Forsyth (1980) suggests that the leisure value should be expressed as a percentage of the net wage (because individuals value leisure time net of direct tax), whereas work time values remain as a percentage of the gross wage. When one does this, the leisure value as a percentage of the wage rate is typically nearly 80% (of the net wage), leaving a smaller margin between leisure and work time values. The explanation for the remaining difference is argued to arise from differential sources of disutility associated with spending the transferred time in leisure compared to income-generating activity which is taxed.

4.7 Valuations for Work and Non-Work Travel

In deciding on a practical resource value we have to establish the nature of the alternative use activity. Rather than assume that all travel time saved is associated with one particular activity (e.g. work or leisure), a lot of time saved in travel involves a mixture of trading off leisure-travel and work-travel. For example, an individual travelling between Auckland and Christchurch by air on business, is likely to travel during a period in which the alternative time use would be partly leisure and partly work time.

There is a continual need to identify typical circumstances in which various trips involve time which is a mix of leisure and work time. One way of helping the process is to focus on elasticities such as for hours worked with respect to the gross wage rate, and the effects of savings in travel time on hours worked and hours of leisure. Forsyth (1980) discusses this issue. The extent to which time savings are associated with changes in leisure time, work time and wage rates is critical to the selection of the final resource values for working time values. The possibility of time savings for a work-related trip being associated with a mix of leisure and work time makes the use of the phrase "value of working time savings" somewhat ambiguous. Current practice is adopted in part for convenience and in part due to the paucity of empirical evidence on the mix of alternative use time between leisure and work time. In application, we need to get away from point estimates and have a value function which can handle case-specific variations in arriving at a truer resource value than the average currently offered. Such a function is promoted in Section 5 and applied to two cases for urban route choice (all trip purposes) and urban commuter mode choice.

4.7.1 Work Time

For all work-related time (i.e. travel taking place during time which is contributing to the productive output of a business), a marginal productivity argument is normally invoked, in which it is assumed that valuation is based on gross income. In resource cost terms, the value of output to the employer equals its return net of any indirect tax. If the resource cost of labour is its price in employment before the removal of income tax (i.e. the market place), then it is traditionally valued before indirect taxation is added.

When work-related travel time, such as a business trip to the airport or to a client's location, occurs during a period commonly thought of as leisure time, a weighted average of the appropriate work and non-work values should be used. The weights represent the proportions of time in and out of *normal* working hours. In the past, all such time has been assumed to occur during normal working hours. Defining normal working hours in respect of alternative time use is quite difficult for some groups in the community. The criteria for determining whether a traveller in saving time is actually trading with leisure time (non-work time) or work time should be determined according to whether the transferred time is converted to an income-generating activity which is subject to tax or not. The use of elasticities is the correct way of determining the substitution mix.

4.7.2 Non-work Time

For non-working or "leisure" time, the willingness to trade time for money approach assumes that the traded money would have been spent on goods which carry indirect taxation. The resources associated with the time trade are thus equal to the expenditure less the indirect taxation. Therefore non-working time savings should be valued at the behavioural value adjusted by the inverse of (1 + the average rate of indirect taxation). Further discussion of this issue is contained in Forsyth (1980). The taxation adjustment is normally applied to an equity value of time savings. That is, a behavioural value which treats everyone as if they had the same mean income (although this is not an approach which should necessarily be recommended). Where the rate of indirect taxation differs widely between alternative use activities, then the application of an average rate will be grossly misleading. Some attention is required to the distribution of actual rates of indirect taxation to establish if this really matters empirically.

4.7.3 Average

The empirical challenge is in establishing the extent of leisure/travel and work/travel substitution. If we had appropriate elasticities, then we could use them to "weight" the respective leisure and work time values to obtain a weighted average VTTS for the particular application context. Since there is likely to be a distribution of combinations of leisure and work trading situations, from a practical point of view we could select an average from the distribution.

4.8 Updating Values Over Time

Updates of time savings values are typically based on kilometre-weighted average gross personal income for the relevant trip purposes and modes. Hours travelling is preferred to kilometres travelled, to allow for the differential influence of traffic congestion. For working time, the marginal wage increment has to be updated to allow for changes in the cost of employment-related "add-ons". If the pattern of trip-lengths for different income groups is likely to change through time; for example the low income trips become longer and the high income trips become shorter, then it is possible that the real value of time savings could decline. This appropriate updating procedure is an added burden because of the general absence of reliable data on kilometres travelled, particularly when it has to be income-related.

4.9 Complementary Inputs to the Valuation Process

Deriving appropriate empirical behavioural, resource and equity values of travel time savings is complicated by a number of complementary inputs to the process.

4.9.1 Average Gross Wage

One of the inputs is the assumed number of annual hours used to convert annual gross personal income to the average gross hourly wage rate. The latter is used as the yardstick for updating VTTS as a percentage of the average wage rate. The correct income used to initially calculate the VTTS as a percentage of the average gross wage rate should be that obtained from the sample used to derive the empirical value of time savings. Often a population-wide average is used instead. It is difficult to establish an appropriate amount of normal hours worked for salaried persons. The often used hours of between 1950 and 2200 per year (based on an average working week of 37.5 to 42 hours) are assumed to supply a meaningful measure of the opportunity cost of the labour resource. With the growing incidence of part-time work and extended working hours of the self-employed, this benchmark is questionable.

The distinction between paid and effectively worked hours seems important if the relationship between the two categories is likely to change over time. It does not matter which definition is used once the empirical values are derived, provided all updates use the same definition and that the relationship between the two definitions is constant over time. If the latter is not true, then the opportunity cost of the labour resource should be based on the effectively worked (i.e. productive) hours, because any savings in travel time become a resource benefit in relation to the actual use of time. However, if as is the situation in most contexts the opportunity cost is the shadow price of an existing resource, then the hourly gross wage rate based on the agreed number of paid hours should be the definitional unit provided we can assume that all paid hours are worked hours.

4.9.2 Occupancy Rate

The occupancy rate of cars has an important influence on the vehicle-level VTTS. The mean estimates of car occupancy must be kept current. The current recommendation in Australia, for example, is 1.6 adults for private urban travel, and 2 adults for private rural travel. The equivalent figures for business trips are respectively 1.4 and 1.6. Levine and Wachs (1996) have recently reviewed this important component of the total time benefit calculation. They argue that the variability in average vehicle occupancy by time of day and day of week (over 7 days) is sufficiently high to call for a much more complex sampling framework than has been used in the past, at least in the USA. Recent research in Australia by Hensher (unpublished) on key intercity corridors suggests leisure travel averages from 1.9 to 2.5 persons per vehicle. This is a substantial variation when converted to passenger trips for the population of traffic.

4.9.3 Journey Attributes in Travel Choice

A problem common to all studies of travel demand is the different interpretations of journey attributes in travel choice data. This gives rise to difficulties in measurement and questions of perception, and hence the basis of selecting an appropriate dimension within which to analyse the behavioural impact of a change in a travel attribute on choice. A four level classification has been suggested in the literature (e.g. UK Department of Environment 1976):

a. *Perceived:* the measure on which decisions are made by the individual which may not be measured by the individual in terms of a recognisable scale.

b. *Reported (perceived):* the answers obtained to questions. This is subject to reporting biases (e.g. rounding, post-purchase bias) and is assumed to be the closest empirical measure of perception.

c. *Synthesised:* that physical measure obtained by the researcher by the use of a statistical model subject to measurement and averaging errors.

d. *Actual:* the actual characteristics of a journey.

The great advantage of recent developments in stated preference/stated choice methods is that the respondents face predetermined levels of attributes of alternatives and are not required to indicate the attribute levels of current and alternative forms of transport or routes. This minimises a major source of error, especially that associated with the attribute levels for non-chosen alternatives. Recent studies on empirical valuation of travel time savings using well designed choice experiments produce time values which can be argued to be our best estimates. The two case studies summarised in Chapter 5 illustrate such evidence.

4.10 Summary

A very clear distinction must be made between behavioural values of travel time savings and resource values. The former should be applied in project evaluation to convert time to money or money to time in the input of a generalised cost or generalised time into a travel demand expression. For conversion of predicted time savings into dollars however a resource value is appropriate. For a leisure-travel trade-off the resource value is an adjusted behavioural value (as described in Section 4.6); for a work-related-travel trade off we promote the production cost approach (Section 4.3).

There are strong theoretical grounds for establishing a range of behavioural values to accommodate the variation in the circumstances under which travel time is transferred from one activity to another. This translates into an appropriate resource value for leisure-travel and work-travel trade-off situations derived from a weighted average behavioural value, where the weights reflect the composition of travel time (e.g. walk, wait, transfer, in-vehicle time). This approach would apply to all travel involving a leisure-travel trade-off (e.g. commuting, social-recreation trips). Where a travel-work trade-off is applicable, the production cost approach is recommended for the calculation of the resource value. If such work travel involves some trade-off with leisure time instead of work time then the leisure value of time savings is implemented for that part of time saved which is unrelated to work. For many work-related trips (especially commercial vehicles), the entire time spent travelling is within accepted working hours.

An empirical review of complementary inputs such as vehicle occupancy and the allocation of travel time between time normally earning an income versus leisure time is critical in establishing the final weighted average time savings in dollars. Without this information, it is very difficult to be confident that we have applied the relevant value of travel time savings and expanded the value of the time savings from the individual to the vehicle to the population of vehicle and/or person trips.

The theoretical literature makes no judgement about whether values of time savings should be point estimates or distributions. There has been however an almost implicit assumption that economic theory produces a single mean estimate. This assumption of convenience is not a restriction of theory. In Chapter 5 we promote the idea of a valuation function to enable the value of travel time savings to vary by whatever are preferred criteria. These might include the size of the time savings, trip length, income, trip cost, travel time variance (i.e. reliability) and any number of socio-economic and demographic characteristics. The analyst then has the opportunity to replace point estimates in a benefit-cost program with an empirical function which can provide more accurate values according to the trip and individuals' characteristics. There is always the option however of selecting an average estimate if necessary. We will discuss valuation functions in the next chapter.

5. Development of Market Research Framework

5.1 Data Types and Paradigms

Transportation researchers have progressed our understanding of individual travel behaviour within a set of modelling paradigms of an essentially economic nature, as represented by the rule of utility maximisation. With rare exception, the mainstream empirical emphasis has been on the application of revealed preference data (RP) in a static discrete choice framework with linear additivity assumed for the functional form of the indirect utility expression associated with each alternative in the choice set.

In recent years interest has grown in extending the RP data paradigm to incorporate stated choice (SC) data as an enrichment tool in contexts where the attribute levels and choice sets extend beyond the utility space observed in real markets. However this extension has stayed essentially within a linear-additive framework and assumed the constant variance assumption of the simple logit model within each of the RP and SC data sub-sets.

Two restrictions of current practice are the emphasis on deriving marginal rates of substitution between attributes such as the value of travel time savings as *point* estimates rather than as functions, and the *uniform* scaling of RP data when combined with SC data. The constant variance assumption normalises the location parameter which scales the taste weight parameter for each attribute. Relaxing the constant variance assumption enables identification of the unique variances and hence scale parameters associated with each alternative in a choice set. The combined extensions into valuation functions and variable scaling of parameters adds further richness to our understanding of human behavioural response to travel opportunities.

Revealed preference data has until recently been the dominating data paradigm in the valuation of travel time savings. RP data are best described as:

1. Depicting the world as it is now (current market equilibrium).
2. Having built-in relationships between attributes (technological relationships are fixed).
3. Having only existing alternatives as observable.
4. Embodying market and personal constraints on the decision-maker.
5. Having high reliability and face validity.
6. Yielding one observation per respondent at each observation point.

In contrast, stated choice (SC) or stated preference (SP) data are best described as:

a) Depicting virtual decision contexts (flexibility).
b) Having controlled relationships between attributes (permitting mapping of utility unctions with technologies from existing ones).
c) Including existing and/or proposed and/or generic choice alternatives.
d) Having difficulty (if not impossibility) to effectively represent changes in market and personal constraints.
e) Being reliable to the extent that respondents understand the task, are committed to the task, and can really respond to the task.
f) Yielding multiple observations per respondent at each observation point.

The distinguishing appeal of the two types of data can be illustrated diagrammatically in the context of mode choice (Figure 5.1). RP data provides information on the current market equilibrium for the behaviour of interest and is useful for short term forecasting of departures from the current equilibrium. In contrast SC data is especially rich in attribute trade-off information, but is to some extent affected by the degree of 'contextual realism' that we can establish for the respondents.

Given the relative strengths of both data types, there is enormous value in using both RP and SC data. The benefits of combining RP and SC data include an ability to map trade-offs over a wider range of attribute levels than currently exists (adding robustness to valuation and for prediction), and an ability to introduce new choice alternatives (accommodating technological change in an expanded attribute space - i.e. relaxing the constraints in the DeSerpa specification). Figure 5.2 illustrates how alternatives in a stated choice experiment imply specific consumption technological constraints of their own.

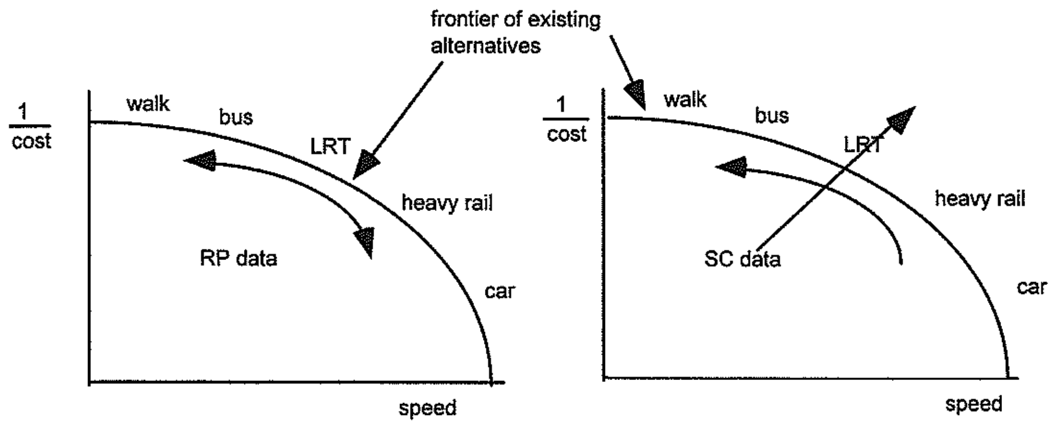

Figure 5.1 Attribute Space of RP and SC Data

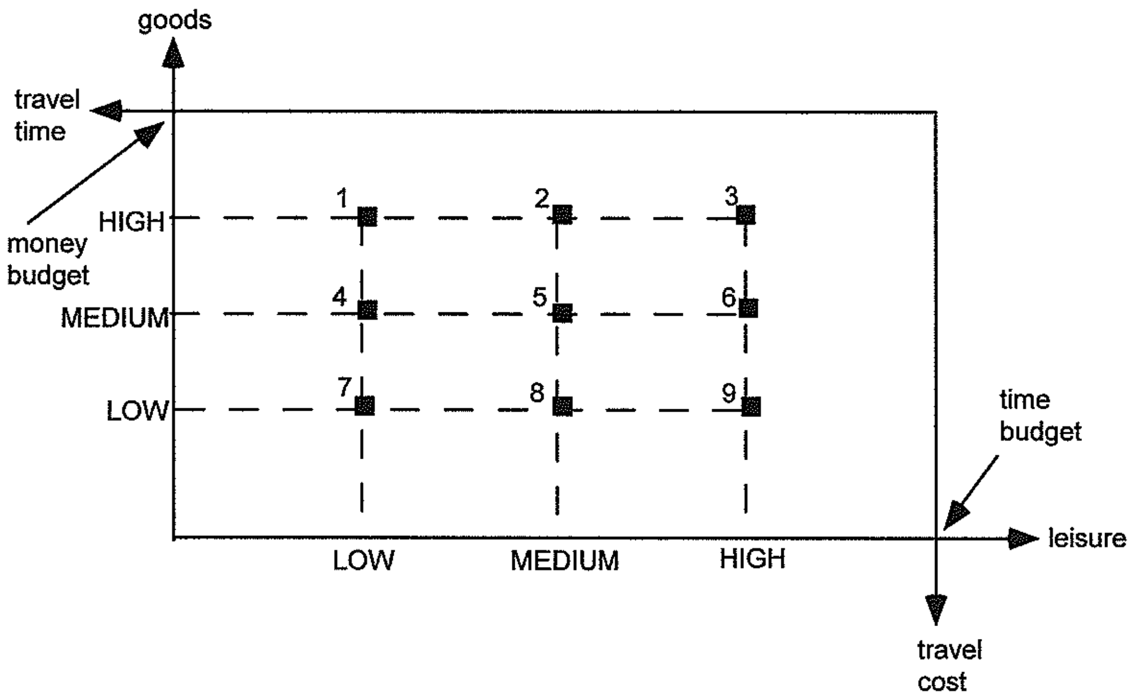

Figure 5.2 Travel Alternatives in a Stated Choice Experiment.

A key role for SC data in a combined SC-RP model is to assist through enrichment in obtaining more robust parameter estimates for a particular RP-based choice model so that in application one can increase the confidence in the predictions as the analyst *stretches* the attribute space and the choice set under policy assessment. However where interest centres only on valuation, estimation of the SC data by itself is sufficient. Given that each replication of a choice experiment is a rich individual observation, with typically 3 to 4 replications per respondent plus an RP observation, one can generate 3 – 4 pairs of SC-RP data or up to 8 observations per respondent.

5.2 Valuation Functions and their Implications

It is typically assumed that the marginal rates of substitution between any two attributes vary by a number of 'market segments' such as mode, trip purpose, trip length and personal income. Within each aggregated market segment, point estimates of behavioural value of travel time savings (VTTS) are routinely derived and applied as mean estimates of an unknown (but assumed) distribution. A strictly linear interpretation of the marginal rate of substitution between travel time and travel cost is assumed within the segment.

We propose an approach which concentrates on a distribution of VTTS derived from the non-linearity inherent in the attributes of alternatives (such as travel time and travel cost), and then mapping these into socio-economic space to identify any systematic variation between VTTS and individual characteristics. This is more appealing and richer than relying on socio-economic characteristics as both proxies for the non-linearity of travel time and travel cost and the role that socio-economic characteristics play as proxies for other unobserved influences on choice and hence value.

A value function is by our definition a functional relationship between VTTS and levels of time and cost both in respect of higher-order (e.g. quadratic) and interaction (e.g. two-way product of time and cost). A segmented valuation function is a value function conditioned on profiles of characteristics of the individual traveller and/or other external influences.

To link the empirical model form to the theory in Chapter 4, we assume that the theoretical parameter κ_i from a theoretical indirect utility function of the linear additive form (DeSerpa 1971, Truong and Hensher 1985) given in equation (6) repeated as (8)

$$V_i = \alpha_i - \lambda C_i - \kappa_i T_i \quad (8)$$

is a function of C_i and T_i:

$$\kappa_i = \kappa\ (T_i, C_i) \quad (9)$$

A Taylor series expansion of (9) around the mean levels $\overline{T}$ and $\overline{C}$ for each alternative *i* (neglecting second order terms) results after rearrangement in equation (10)

$$V = \grave{\alpha}_i - \lambda C_i - \overline{\kappa} T_i + (\beta T_i^2 + \gamma C_i T_i + \omega) \quad (10)$$

where

$\beta = (\partial\kappa/\partial T)_i, \gamma = (\partial\kappa/\partial C)_i$, and $\omega = -\beta\overline{T} - \gamma\overline{C}$.

By neglecting second-order terms in (10) we implied that $\partial\kappa/\partial T$ and $\partial\kappa/\partial C$ are constants, independent of alternative i. Equivalently, the parameters ω, β and γ are unsubscripted. The VTTS can now be derived from (10) as follows (Hensher and Truong 1983, Hensher 1995):

$$VTTS = \frac{\partial V/\partial T_i}{\partial V/\partial C_i} \Big| V_i = \text{constant}$$

$$= \frac{-\overline{\kappa} + \gamma C_i + 2\beta T_i}{-\lambda + \gamma T_i} \qquad (11)$$

Thus VTTS is dependent on the levels of travel time and cost. This formula can be generalised to account for the disaggregation of travel time (Hensher and Truong 1983). We can introduce interactions between each travel time and between travel time and other attributes of alternatives. The ability to enrich the valuation function to test for a richer specification is conditioned by the quality of data.

Revealed preference data is usually somewhat limiting in its ability to offer sufficient richness in both variability and correlation structure to enable each potential influence to be included without producing confoundment. This is particularly true when accounting for non-linearity and when 'new' alternatives are assessed for market share. Data derived from a stated choice experiment however increases the opportunity to account for the independent (ie additive) contribution of each source of variability in the valuation function in an expanded choice set. It is for this reason, amongst other reasons, that the stated choice paradigm has evolved to become an important feature of a preferred empirical approach to obtaining behavioural values of travel time savings (Bradley et al 1996).

5.3 Sample Case Studies

5.3.1 Case Study I: Urban Commuter Mode Choice

As part of a study investigating the impact of transport policy instruments on reductions in greenhouse gas emissions in six Australian capital cities (Hensher et al 1995), a stated choice experiment centred on commuter mode choice was designed (Louviere et al 1994). The universal choice set comprised the currently available modes plus two 'new' modes – light rail and busway.

There were 12 types of showcards, with three trip lengths and four combinations of public transport: bus vs. light rail, bus vs. train (heavy rail), busway vs. light rail, and busway vs. train.

Four mode choice models were estimated as the basis for deriving a valuation function in the presence and absence of constant variance in the random component of a utility expression for a discrete choice model. The four models were: Basic logit model (BL), Heteroscedastic extreme value logit model (HEVL), Basic non-linear logit model (BnlL) and Heteroscedastic extreme value non-linear logit model (HEVnlL).

The HEV models allow the variance of the random components of the choice model to vary in contrast to the basic logit model which assumes that the variances are the same across all modes - the latter referred to as the constant variance or independence of irrelevant alternatives assumption. Thus the HEV model is potentially more realistic since useful information does exist

in the random component of utility since it accounts for the sources of unobserved influences on choice. These unobserved influences are unlikely to impact identically across the modes.

The BL and HEVL models include stand-alone linear travel times and costs capable of producing only point estimates of VTTS; the BnlL and HEVnlL models allow for quadratic terms for travel time and/or interactions between cost and time to enable the derivation of a valuation function for travel time savings. The mean estimates of VTTS for all 4 models are given in Table 5.1.

Table 5.1. Mean Estimates of Commuter Values of Travel Time Savings ($/person hour)

	BL	HEVL	BnlL *	HEVnlL *
Drive Alone	6.50	6.69	7.21	7.12
Ride Share	6.50	6.69	7.21	7.12
Bus	7.51	3.44	6.37	7.54
Train	7.51	3.44	6.37	7.54
Light Rail	7.51	3.44	6.37	7.54
Busway	7.51	3.44	6.37	7.54

* columns are based on sample mean time and cost

An important result emerges from a comparison of the BL and HEVL models. The mean VTTS for public transport is substantially lower when we relax the constant variance assumption. In contrast the mean VTTS for drive alone and ride share is slightly higher. The reasoning lies in the variance estimates. The mean estimate of variance varies substantially across the four public transport modes, given busway is set equal with 1.00. The large variance associated with unobserved effects which clearly are more prominent for public transport appear to have confounded the contribution of time and cost in public transport more than for the automobile.

Consequently the inflated VTTS for public transport in the basic logit model is the result of failure to account for some unobserved influences on relative utility which are suppressed through the constant variance assumption and consequently 'distributed' to the observed effects. However when we introduce non-linearity into the VTTS estimate expressed as a valuation function we find that at the mean of the sample travel time and costs that the higher VTTS associated with the basic linear model is 'reinstated' for public transport. The fact that we have a similar value at the mean of the sample for HEVnlL does not imply that the basic linear model is 'correct'; rather it suggests in this single empirical study that the downward valuation for public transport VTTS, consequent on allowing for non-constant variance in a linear specification, is approximately offset by an upward valuation after allowing for non-linearity in the non-constant variance model, producing a result at the sample mean very close to that of a constant variance model with linearity. What is of more importance is the distribution of values across the sample summarised in Table 5.1 for a range of travel times and costs for each of the 6 modes.

The range of VTTS BnlL and HEVnlL in Table 5.2 may appear to be similar, but in fact the differences are quite substantial, especially for public transport. The only mode with consistently similar VTTS is car drive alone. For the other modes, the difference can be as high as 90%, with the HEVnlL model producing higher VTTS. The implications for forecasts of user benefits in transport project evaluation is clear - there is the potential for substantial differences in the net benefits to different segments of the travelling market. Currently simple mean point estimates have the following properties in the current study: they over-estimate the time benefits for, train, light-rail and busway trips, and under-estimate them for the shorter train trips, longer car drive alone and bus trips. These findings translate to the distribution of VTTS by mode derived from distributions of actual market times and costs.

Table 5.2 VTTS distribution in travel time and cost space for each commuter mode based on a synthesised range of times and costs – BnlL model (HEVnlL in parenthesis).

	DA	RS	BS	TN	LR	BWY
c=1, t=20	8.22 (8.25)	7.96 (7.56)	7.12 (8.34)	5.12 (5.81)	6.48 (7.70)	4.97 (8.13)
c=1, t=25	9.09 (9.13)	8.58 (7.80)	9.41 (10.54)	4.48 (4.80)	5.49 (6.99)	4.42 (8.49)
c=1, t=30	10.16 (10.21)	9.29 (8.05)	11.71 (12.74)	3.98 (4.10)	4.50 (6.29)	3.97 (8.90)
c=1, t=35	11.53 (11.59)	10.14 (8.32)	14.00 (14.93)	3.59 (3.57)	3.51 (5.58)	3.61 (9.34)
c=1, t=40	13.31 (13.40)	11.16 (8.61)	16.29 (17.13)	3.26 (3.17)	2.52 (4.87)	3.31 (9.83)
c=1.5, t=20	7.64 (7.67)	7.53 (7.38)	7.12 (8.34)	5.97 (7.06)	6.48 (7.70)	5.72 (7.86)
c=1.5, t=25	8.45 (8.49)	8.11 (7.61)	9.41 (10.54)	5.23 (5.84)	5.49 (6.99)	5.08 (8.22)
c=1.5, t=30	9.45 (9.50)	8.79 (7.86)	11.71 (12.74)	4.65 (4.98)	4.50 (6.29)	4.57 (8.61)
c=1.5, t=35	10.72 (10.78)	9.59 (8.12)	14.00 (14.93)	4.19 (4.34)	3.51 (5.58)	4.16 (9.04)
c=1.5, t=40	12.38 (12.46)	10.56 (8.40)	16.29 (17.13)	3.81 (3.85)	2.52 (4.87)	3.81 (9.52)
c=2, t=20	7.07 (7.09)	7.10 (7.19)	7.12 (8.34)	6.82 (8.31)	6.48 (7.70)	6.48 (7.60)
c=2, t=25	7.82 (7.85)	7.65 (7.42)	9.41 (10.54)	5.97 (6.87)	5.49 (6.99)	5.75 (7.95)
c=2, t=30	8.74 (8.78)	8.29 (7.66)	11.71 (12.74)	5.31 (5.86)	4.50 (6.29)	5.18 (8.33)
c=2, t=35	9.91 (9.97)	9.05 (7.92)	14.00 (14.93)	4.78 (5.11)	3.51 (5.58)	4.70 (8.74)
c=2, t=40	11.45 (11.53)	9.95 (8.19)	16.29 (17.13)	4.35 (4.53)	2.52 (4.87)	4.31 (9.20)
c=2.5, t=20	6.49 (6.52)	6.67 (7.01)	7.12 (8.34)	7.68 (9.56)	6.48 (7.70)	7.23 (7.34)
c=2.5, t=25	7.18 (7.21)	7.19 (7.23)	9.41 (10.54)	6.72 (7.91)	5.49 (6.99)	6.42 (7.68)
c=2.5, t=30	8.03 (8.07)	7.79 (7.47)	11.71 (12.74)	5.98 (6.75)	4.50 (6.29)	5.78 (8.04)
c=2.5, t=35	9.11 (9.16)	8.50 (7.72)	14.00 (14.93)	5.38 (5.88)	3.51 (5.58)	5.25 (8.44)
c=2.5, t=40	10.52 (10.59)	9.35 (7.99)	16.29 (17.13)	4.89 (5.21)	2.52 (4.87)	4.81 (8.89)
c=3, t=20	5.92 (5.94)	6.24 (6.83)	7.12 (8.34)	8.53 (10.81)	6.48 (7.70)	7.98 (7.08)
c=3, t=25	6.54 (6.57)	6.72 (7.04)	9.41 (10.54)	7.47 (8.94)	5.49 (6.99)	7.09 (7.41)
c=3, t=30	7.32 (7.35)	7.29 (7.27)	11.71 (12.74)	6.64 (7.63)	4.50 (6.29)	6.38 (7.76)
c=3, t=35	8.30 (8.35)	7.95 (7.52)	14.00 (14.93)	5.98 (6.65)	3.51 (5.58)	5.80 (8.14)
c=3, t=40	9.59 (9.65)	8.75 (7.78)	16.29 (17.13)	5.44 (5.89)	2.52 (4.87)	5.31 (8.57)
c=3.5, t=20	5.34 (5.36)	5.81 (6.64)	7.12 (8.34)	9.38 (12.06)	6.48 (7.70)	8.73 (6.82)
c=3.5, t=25	5.91 (5.93)	6.26 (6.85)	9.41 (10.54)	8.22 (9.98)	5.49 (6.99)	7.76 (7.13)
c=3.5, t=30	6.61 (6.64)	6.78 (7.08)	11.71 (12.74)	7.31 (8.51)	4.50 (6.29)	6.98 (7.47)
c=3.5, t=35	7.50 (7.54)	7.40 (7.31)	14.00 (14.93)	6.58 (7.42)	3.51 (5.58)	6.35 (7.84)
c=3.5, t=40	8.66 (8.72)	8.15 (7.57)	16.29 (17.13)	5.98 (6.58)	2.52 (4.87)	5.82 (8.26)
Range:						
BnlL	5.34 - 13.31	5.81 - 11.16	7.12 - 16.29	3.26 - 9.38	2.52 - 6.48	3.31 - 8.73
HEVnlL	5.36 - 13.40	6.64 - 8.61	8.34 - 17.13	3.17 - 12.06	4.87 - 7.70	6.83 - 9.83

5.3.2 Case Study II: Urban Toll Route Choice

As part of the development of a system of privately financed toll roads and tunnels within the Sydney Metropolitan Area, the New South Wales Roads and Traffic Authority (RTA) evaluated the costs and benefits of a tunnel under one of Sydney's busiest traffic intersections, Taylor

Square. This intersection was a bottleneck for north-south traffic which benefited from upgrading of the freeway system except for a few kilometres of road through Taylor Square. The Institute of Transport Studies was engaged to identify the sensitivity of the relevant travelling population to alternative levels of tolls in the context of varying potential savings in travel time. A stated choice experiment was designed to determine the route choice made under different toll-travel time regimes.

The choice experiment involved asking each sampled traveller to choose a tolled or a free route from the two routes offered. A tolled route was defined in terms of three variables: a toll (with levels of $0.50, $1 and $1.50), total travel time and a delay time (always set at zero). A free route is defined in terms of a zero toll, total travel time and delay travel time. Total time is the sum of delay and free moving time. Models were estimated for five trip purposes (private commute, business commute, travel as part of work, social-recreation and other personal business).

The behavioural values of travel time savings as a function of the level of toll and trip length (in minutes) expressed in dollars per person hour are reported in Table 5.2 for a reasonable range of tolls ($1 to $2) and trip lengths for the tolled section of the trip (5 to 10 minutes).

For each trip purpose segment, we observe VTTS increasing for a given travel time as the toll level increases, and decreasing for a given toll level as travel time increases. Thus the VTTS is inversely related to trip length. That is, for a given toll, an individual is willing to outlay less money to save a unit of time for longer trips compared to shorter trips. This finding is consistent with the results reported by Hensher (1975). As might be expected, the variation in VTTS is relatively flat in models where the two-way interaction between toll and travel time is not statistically significant (i.e. social-recreation travel): the range within Table 5.3 is $4.85 to $7.73 per person hour.

To assess the empirical implications of deriving a valuation function and hence a distribution of VTTS from a model estimated on the actual attribute levels, we re-estimated the private commuter model. The VTTS in brackets in Table 5.3 derived from this model are consistently smaller and noticeably flat.

If we use the mean travel time and toll in the choice experiment for the toll route, we find that the VTTS is close to the figure in bold in Table 5.3 for each trip purpose segment. Some comments are required. Travel as part of work is a potentially problematic category to handle via a utility framework. The marginal productivity approach is preferred. The estimate above appears to represent what the driver (who completed the form) is willing to pay to save travel time and is not the full opportunity cost plus disutility cost. The trade-off suggests the component VL in equation (7) in Chapter 4 might be expected to be relatively lower for such travellers compared to business commuters. As a percentage of the average wage rate the 'travel as part of work' VTTS varies between 10% and 71%, depending on the toll/time combination. The evidence offered in Chapter 3 from three European countries ranges from 32% to 61%. Our estimate at the mean of the choice experiment is 20% of the average wage rate, which is identical to that found for the leisure value in the 1977 study of people travelling as part of work. We may have picked up travel where there is a high proportion of travel taking place outside of normal working hours.

Table 5.3 Behavioural VTTS Derived from a Valuation Function

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

Note: 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 commuters are derived from a model estimated on actual levels of attributes.

5.4 Summary of Implications for VTTS Market Research

The case for using stated choice data for deriving behavioural values of travel time savings for leisure travel, and the opportunity cost component of a work travel model is gathering empirical support very quickly. Where a rich revealed preference data set is also collected co-jointly, it is useful to jointly estimate an RP-SP model with appropriate re-scaling to check the usefulness of the SP stand-alone VTTS. Since the VTTS is derived from a ratio of two parameters in a linear model yielding a point estimate and from the ratio of more than two parameters in a non-linear model yielding a valuation function, the importance of using a mixed RP-SP model is less than where one is interested in deriving elasticities and prediction of demand which need choice probability outputs which are not reliable in a stand-alone SP model environment.

We would thus strongly suggest that future empirical market research capture data describing the market context in which individuals actually make choices (i.e. RP data on at least two alternatives including the chosen alternative), as well as an enrichment data source defined by a stated choice experiment in which individuals make choices from an enriched set of attributes, attribute levels and alternatives in the choice set. The SP experiment typically provides greater variability in attribute levels than offered in the market and hence adds a richness necessary for deriving distributions of VTTS which is often limited in an RP setting. This does not mean that RP data cannot deliver such richness, but that it is our experience that RP data alone is less rich than the combined RP and SP data sources. The SP experiment however must relate to attributes and levels that are meaningful to respondents and where possible are defined as a variation of currently experienced levels of such attributes.

Valuation functions or distribution of behavioural values are promoted as a way of delivering adjustments for size of time savings, trip length, congestion and socio-economic segmentation (e.g. income). The analyst has the richness of information to aggregate and average as they see fit. In the limit we can have one single average.

6. Market Research Proposals

6.1 Introduction

This chapter provides an outline of the proposed scope and approach for the Stage II Market Research Programme.

The original Research Brief envisaged that Stage II itself would be concerned with further research into the valuation of the disutility associated with travel on unsealed roads (relative to sealed roads). It also noted that subsequent market research might cover:

- Roads with poor alignment (disutility);
- Congested travel conditions and travel time uncertainty (disutility);
- Conditions with restricted passing opportunities (disutility);
- Businesses travel (opportunity costs); and
- 'Pure' leisure travel.

It commented that the priorities for further market research would be recommended in the Stage I report.

As a result of discussions with Transit staff in relation to Stage I, Transit has advised that top priority for market research in Stage II should now be given to investigation of the disutility associated with travel on rural roads in situations with restricted passing opportunities (resulting from poor alignment and/or heavy traffic flows). This should take precedence over further research on the disutility associated with unsealed roads or on any of the other aspects noted above.

The remainder of this chapter therefore provides a broad outline and structure for this research. The development of the methodology and the survey design itself are part of the Stage II tasks.

6.2 Market Research Objectives and Scope

The Stage II market research is to address the disutility experienced by motorists travelling on rural roads when their speeds are restricted to being significantly below prevailing speeds on rural roads generally (typically 90-100 km/hr). Such speed restrictions are principally associated with restrictions on passing opportunities (resulting from poor alignment and/or heavy traffic flows relative to the road capacity); but may also result from the poor alignment restricting free-flow speeds. Measures which might reduce this disutility are general road widening (e.g. conversion from 2 lane to 4 lane road), provision of passing lanes, and/or improvement of alignment (easing of curves, improving sight distances etc.).

The main emphasis of the market research is to identify the extent of disutility in such situations, ie. to establish the incremental VTTS for such situations relative to the 'standard' VTTS values for travel on rural roads (i.e. relating to largely free-flow conditions). For business travel, the survey will cover the employee disutility component of VTTS only, not the full opportunity cost to the employer.

6.3 Outline of Proposed Stage II Approach

6.3.1 Overview

The original Research Brief envisaged the following tasks within Stage II:

Task 1: Development of Methodology
Task 2: Questionnaire and Sampling Design
Task 3: Pilot Survey
Task 4: Main Survey Fieldwork
Task 5: Data Analysis
Task 6: Interpretation of Survey Results
Task 7: Stage II Report.

Although these tasks were based on Stage II being concerned with the disutility associated with travel on unsealed roads, they remain valid for the market research now proposed.

The methodology proposed will follow a similar approach to that described in the previous chapter for assessing the response to an urban toll route (refer Section 5.3.2). Stated choice (SC, sometimes known as stated preference SP) methods would be used. The following provides a summary of key aspects of the survey design (to be developed further within Stage II, Tasks 1 and 2).

6.3.2 Survey Population

The survey would cover a sample of car travellers using rural roads in New Zealand. Both car drivers and their passengers would be surveyed. Travel for all trip purposes would be covered.

6.3.3 Survey Strategy

Face-to-face personal interview methods are regarded as most appropriate in this case. The interviews will obtain information about the current trip before selecting the appropriate set of context-specific show cards for levels of time and cost, which makes mail-out/mail-back methods unsuitable. Telephone surveys are regarded as less suitable than face-to-face interviews, as telephone methods are more limited in the information that can be obtained, are less reliable in terms of response quality, and suffer from high rejection rates for SC experiments.

6.3.4 Sample Selection

It is proposed that the survey takes place at wayside stops, garages etc. on selected rural routes. A stratified random sampling approach will be used, with interviewing continuing until the minimum quota in each sample stratum has been obtained. The precise survey locations will be selected in Stage II Task 2.

6.3.5 Response Rates

Response rates for face-to-face personal interview are generally high, typically at least 60-70%. If survey forms are handed out for self-completion and then collected, response rates may be up to 50%. Mail-back questionnaires would typically have response rates up to around 30%.

6.3.6 Sample Segmentation

The sample would be segmented by key variables, including:

- Trip purpose
- Trip length
- Income

6.3.7 Sample Sizes

The sample size appropriate is clearly dependent on the extent of segmentation involved in the survey. Sample sizes will need to increase if there is interest in segmentation by trip length, income, time of day etc. As an indication only at this stage, a sample of at least 1000 carefully segmented individuals (stratified random sample) is suggested for each trip purpose.

6.3.8 Experimental Design

The survey would focus on car drivers/passengers' trade-offs between alternative characterised by three main variables, i.e.:

- Total travel time
- Toll charge (may be zero) or other out-of-pocket cost
- Extent of speed restrictions

The way in which the 'extent of speed restrictions' is to be specified needs further consideration (and piloting). Potential methods of specification (singly or in combination) include:

- Distance between passing opportunities, e.g. 2, 5, 10, 20 kilometres
- Time before passing opportunities, e.g. 1, 2, 5, 10, 20 minutes
- Severity of speed reductions, e.g. 10, 20, 30, 40 km/hr below free-flow speed

In the survey design phase, an appropriate choice set for survey would be selected from the potential combinations of the above main variables. Each variable would have at least three levels specified in experimental design. The design would also specify the specific choice sets/levels between which respondents would be asked to indicate their preference.

6.3.9 Piloting

A pilot survey will be essential. We do not consider that there is any necessity to hold any focus group discussions initially, in order to assist in survey design.

6.3.10 Outputs

The outputs of the survey will be VTTS behavioural functions, disaggregated by trip purpose, trip length, income etc. as well as by the extent of delay/congestion. Adjustments will be needed to these (for taxation) to derive resource values. These can then be combined and aggregated as appropriate to derive values for use in project evaluation.

6.4 Next Steps

Provided that the above general approach to the Stage II market research is supported, then further survey development can take place within Stage II itself. The survey methodology will need to be developed further in order to determine an appropriate budget for Stage II: this could be done either within Task 1 (as originally envisaged) or as part of the development of a more detailed Stage II Research Brief.

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