VALUATION OF TRAVEL TIME SAVINGS

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AN IMPORTANT NOTE FOR THE READER

The research detailed in this report was commissioned by Transit New Zealand when it had responsibility for funding roading in New Zealand. This funding is now the responsibility of Transfund New Zealand.

ABBREVIATIONS

ARC	Auckland Regional Council
ATM	Auckland Transport Models
AGWR	average gross wage rate
AWR	average wage rate
BTE	Bureau of Transport Economics
CBR	Commonwealth Bureau of Roads
DoE	Department of Environment, UK
DoT	Department of Transport, UK
GATS	Greater Wellington Area Transportation Survey
GDP	Gross domestic product
GST	Goods and services tax
h	hour(s)
LGORU	Local Government Operations Research Unit, UK
LTSA	Land Transport Safety Association, NZ
MoT	Ministry of Transport, UK
MOT	Ministry of Transport, NZ
MPL	Marginal productivity of labour
MVA	Martin Vorhees Associates Consultancy
NRB	National Roads Board
NZ	New Zealand
p	UK pence
PEM	Project Evaluation Manual
PTRC	Planning and Transport Research & Computation International Association
RCS	rate of commodity substitution
RP	revealed preference
RRU	Road Research Unit
RTA	Road Traffic Authority, NSW
SP	stated preference
SACTRA	Standing Advisory Committee on Trunk Road Assessment
TRB	Transportation Research Board, USA
TRL	Transportation Research Laboratory, UK
UK	United Kingdom
USA	United States of America
UTC	Urban Transport Council
VOC	Vehicle operating costs
VOL	Value of life
VOT	Value of time
VTT	Value of travel time
VTTS	Value of travel time savings
WRC	Wellington Regional Council
WTP	Willingness-to-pay

CONTENTS

EXECUTIVE SUMMARY 7
ABSTRACT 10
1. INTRODUCTION 11
1.1 Background and Objectives 11
1.2 Definition of a "Value of Travel Time Savings" 11
1.2.1 Resource Values 12
1.2.2 Behavioural Values 12
1.2.3 Equity Values 12
1.3 Scope of Project 13
1.4 Structure of This Report 13

2. BRIEF HISTORY & DEVELOPMENT OF VALUATION OF TRAVEL TIME SAVINGS 14
2.1 International Developments 14
2.1.1 United Kingdom 14
2.1.2 United States of America 15
2.1.3 Australia 15
2.1.4 Netherlands 15
2.2 New Zealand Developments 16
2.2.1 Ministry of Works & National Roads Board 16
2.2.2 Urban Transport Council 16
2.2.3 Transit New Zealand 17
2.3 Current PEM VTTS and Their Basis 17
2.3.1 Work Travel 17
2.3.2 Non-Work Travel Time 20
2.3.3 Base VTTS for Car Drivers 20
2.3.4 Car Passengers 21
2.3.5 Bus Passengers 21
2.3.6 Walking and Waiting for Transport 21
2.3.7 Trip Purpose 22
2.3.8 Modifying Factors for Traffic Congestion and Reliability 22
2.3.9 Modifying Factors for Comfort 22
2.3.10 Modifying Factors for Person Type 22
2.3.11 Freight Time Savings 22
2.4 Treatment of Public Transport in PEM 23

3. STATE OF KNOWLEDGE & PRINCIPAL AREAS OF UNCERTAINTY 24
3.1 General 24
3.2 Theoretical Basis 24
3.2.1 Restatement of the Microeconomic Theory 24
3.2.2 Non-Linearity in VTTS 26
3.2.3 Effects of Congestion and Unpredictability of Travel Times 27
3.2.4 Taxation Treatment 28
3.2.5 Compatibility of Travel Time and Accident Valuation Approaches . . 28
3.3 Methods and Findings from Behavioural Studies 28
3.3.1 Methodologies for Behavioural Studies 29
3.3.2 Opportunities for Behavioural Studies in New Zealand 29
3.3.3 Valuation of Working Time 30
3.3.4 VTTS Relating to Commercial Vehicles 31
3.3.5 Evidence on Behavioural VTTS 32
3.3.6 Equity Issues 33
3.3.7 VTTS for "Slow" Transport Modes 33

3. **STATE OF KNOWLEDGE & PRINCIPAL AREAS OF UNCERTAINTY** continued:
3.4 Transferability of International Research ... 34
3.5 Practical Application for Project Planning and Evaluation ... 35
3.5.1 Issues Regarding Application of Time Values in Travel Demand Modelling and Project Evaluation ... 35
3.5.2 Future Trends in Travel Time Values ... 35
3.5.3 Requirements for Representative Travel Time Data ... 36
3.5.4 Treatment of Speed Limits in Evaluating Travel Time Savings ... 37

4. **PROPOSED RESEARCH PROGRAMME** ... 38
4.1 Basis of Research Programme Development ... 38
4.2 Outcome of Workshop ... 38
4.3 Candidate Research Projects ... 39
4.3.1 Project No. 1: Treatment of Taxation, and Compatibility of VTTS and Value of Statistical Life ... 39
4.3.2 Project No. 2: Stated Preference Study of Car Users on Rural Highways 40
4.3.3 Project No. 3: VTTS for Business Travellers ... 41
4.3.4 Project No. 4: Valuation of Commercial Vehicle Time Savings ... 43
4.3.5 Project No. 5: Representative Travel Data ... 43
4.3.6 Project No. 6: Forecasting and Updating Unit Time Values ... 45
4.3.7 Project No. 7: Stated Preference/Revealed Preference Study of Route Choice, Tauranga Harbour Bridge ... 46
4.3.8 Project No. 8: Modelling and Evaluation of Time Savings and User Benefits in Urban Transport Networks ... 47
4.4 Establishment of Research Programme Priorities ... 48
4.5 Other Issues for Further Consideration ... 51
4.5.1 Equity Issues ... 51
4.5.2 Transferability of International Research ... 51
4.5.3 Treatment of Speed Limits in Evaluation ... 51
4.5.4 VTTS Research in Main Urban Centres ... 52
4.5.5 Public Transport Project Evaluation ... 52

APPENDICES
A1. NON-LINEARITY IN VALUES OF TRAVEL TIME SAVINGS ... A-55
A2. EFFECTS OF CONGESTION & UNPREDICTABILITY OF TRAVEL TIMES ... A-62
A3. TAXATION TREATMENT ... A-66
A4. COMPATIBILITY OF TRAVEL TIME & ACCIDENT VALUATION APPROACHES ... A-69
A5. METHODOLOGIES FOR BEHAVIOURAL STUDIES ... A-71
A6. VALUATION OF WORKING TIME ... A-75
A7. VALUATION OF TRAVEL TIME SAVINGS RELATING TO COMMERCIAL VEHICLES ... A-82
A8. EVIDENCE ON BEHAVIOURAL VALUES OF TRAVEL TIME SAVINGS ... A-86
A9. EQUITY ISSUES ... A-96
A10. VTTS FOR "SLOW" TRANSPORT MODES ... A-99
A11. TRANSFERABILITY OF INTERNATIONAL RESEARCH ... A-102
A12. ISSUES IN APPLICATION OF VALUES OF TRAVEL TIME SAVINGS IN TRAVEL DEMAND MODELLING & ECONOMIC EVALUATION ... A-105
A13. FUTURE TRENDS IN TIME VALUES ... A-112
A14. TREATMENT OF SPEED LIMITS IN EVALUATING TRAVEL TIME SAVINGS ... A-114
A15. REQUIREMENTS FOR REPRESENTATIVE TRAVEL DATA ... A-118
A16. EVIDENCE FROM URBAN TRANSPORT STUDIES IN NEW ZEALAND ... A-120
A17. THEORETICAL BASIS OF THE VALUE OF TRAVEL TIME ... A-122
A18. VALUE OF TRAVEL TIME SAVINGS FOR CHILDREN ... A-126

REFERENCES ... 130

EXECUTIVE SUMMARY

1. The Project

This report covers Stage 1 of a review, undertaken largely in 1992, of the values of travel time savings (VTTS) used to evaluate road projects in New Zealand, that also lists the priorities for further research to develop improved VTTS.

The project included:

- A review of more recent international and New Zealand research on VTTS and a summary of the basis of the time values used in the 1991 Transit New Zealand Project Evaluation Manual (PEM).
- An appraisal of the state of knowledge internationally, and in New Zealand, of VTTS, highlighting the principal areas of uncertainty and deficiencies in knowledge.
- An appraisal of the principal areas of weaknesses, identified in the PEM values, in the light of the international evidence, and the development of a research programme and priorities to address those aspects where further research would be most cost-effective.

Travel time savings comprise the major portion of the benefits of many road improvement projects, particularly in urban areas. Thus unit VTTS are one of the most crucial inputs to the social cost benefit evaluation methodology. Therefore values that are as accurate as possible are important to the accuracy of evaluations.

2. Review of International Research

A review was undertaken of more recent international VTTS research and developments. It focused primarily on major studies and reviews carried out over the last ten years in the United Kingdom, the Netherlands and Australia.

3. Review of New Zealand Developments and Current Values

The historical developments in VTTS research and reviews in New Zealand are documented. The values used in the PEM are described together with the theoretical and practical basis used for them. Aspects of particular weakness or uncertainty were noted.

4. State of International Knowledge

The state of the international research on valuation of travel time savings, its application to New Zealand roads and areas of weakness, were examined based on the following four categories:

- Theoretical basis,
- Methods and findings from behavioural studies,
- Transferability of international research,
- Practical application for project planning and evaluation.

4.1 Theoretical basis

- Non-linearity of values.
- Effects of congestion and unpredictability of travel time.
- Treatment of taxation.
- Consistency of travel time and accident valuation approaches.

4.2 Methods and findings from behavioural studies

- Roles for stated preference (SP) and revealed preference (RP) studies.
- Opportunities for behavioural studies in New Zealand.
- Approach to valuation of working time (probably one of the major areas of weakness in current PEM values).
- Valuation of time savings relating to commercial vehicles.
- Behavioural time valuations, and their variation with person type, trip purpose, trip length, etc.
- Implications of adoption of "equity" values of time averaged across different income and traveller groups.

4.3 Transferability of international research

Given the complexity of VTTS research, the substantial body of international research now available, and the relative paucity of studies in New Zealand, there will continue to be a need for the transfer of international research results for use in New Zealand. The issues involved in such transfers are outlined and suggestions are made for future work on this topic.

4.4 Practical application for project planning and evaluation

- The interaction of travel demand modelling and project evaluation methods, including the treatment of elastic (variable) demand and the use of behavioural and resource values of time savings.
- Basis for forecasting future trends in VTTS.
- Requirements for representative travel data to assist in application of values for specific project evaluations.
- Treatment of speed limits in evaluating time savings.

5. Development of Research Programme

An outline research programme into issues relating to VTTS in New Zealand was developed, guided by the following criteria:

- The degree of uncertainty which the present lack of information or knowledge has on road project planning and evaluation in practice.

- The likelihood of research gaps being filled by international research which can be transferred to the New Zealand context.
- The resources required for research projects, in terms of expertise and cost, and the amount of research funding which Transit New Zealand can reasonably afford to expend on the topic.
- The likelihood of projects achieving their target objectives and the pay-off in terms of improved confidence in road planning and evaluation procedures.

In the light of these criteria, first priority should be given to research on aspects of VTTS which are peculiar to New Zealand, and would therefore not be filled by any international research efforts. Second priority should be given, if research resources allow, to a programme of empirical studies designed to provide reference values of time savings in commonly occurring evaluation contexts. These would focus on valuations for urban and rural road transport in situations where modal substitution is not an issue.

Draft research briefs were developed for eight research projects (some of which involved several stages) and costs were estimated for each. The potential pay-off of each project was evaluated against a range of criteria based on those noted above; the criteria were weighted and a weighted "effectiveness" score for each project was derived. Projects were then ranked in terms of cost:effectiveness ratios. These rankings were used to group the projects into the following three priority categories.

Priority 1:
- Treatment of Taxation, and Compatibility of VTTS and Value of Life
- VTTS for Business Travellers
- Stated Preference/Revealed Preference Study of Route Choice: Tauranga Harbour Bridge

Priority 2:
- Stated Preference Study of Car Users on Rural Highways
- Representative Travel Data
- Modelling and Evaluation of Time Savings and User Benefits in Urban Transport Networks

Priority 3:
- Valuation of Commercial Vehicle Time Savings
- Forecasting and Updating Unit Time Values.

ABSTRACT

A review of the values of travel time savings used for the evaluation of road projects in New Zealand and incorporated in the 1991 Transit New Zealand Project Evaluation Manual was undertaken, largely in 1992. Travel time savings comprise the major portion of the benefit of many road improvement projects, and thus the unit values of time savings are a crucial input to road project evaluations. The basis of the unit time values used in the Project Evaluation Manual was described, highlighting the aspects of particular weakness or uncertainty.

The state of international knowledge on travel time values was reviewed in detail, under four main headings:

- Theoretical basis
- Methods and findings from behavioural studies
- Transferability of international research
- Practical application for project planning and evaluation.

An outline research programme on valuation of travel time savings was developed for New Zealand, and priorities were established based on cost:effectiveness ratios.

1. INTRODUCTION

1.1 Background and Objectives

This is the final report of a Transit New Zealand Research Project on "Valuation of Travel Time Savings". This project was undertaken, largely in 1992, by Symonds Travers Morgan (NZ) Ltd in association with Beca Carter Hollings & Ferner Ltd (Beca) and with further specialist inputs by Professor David Hensher of Sydney University.

The Value of Travel Time Savings (VTTS) is a key component in the planning and evaluation of transportation projects in New Zealand and overseas. In project planning, travel time is recognised as the major economic (user) factor influencing route choice and a very significant factor in choice of travel mode, choice of travel destination, and in the decision to travel at all.

In project evaluation, based on the principles of social cost benefit analysis, road user benefits are the primary social benefits of transportation projects. These benefits flow through the economy in a variety of ways, but for most practical purposes they are most readily measured where they initially occur, as reductions in travel time, as reductions in travel cost, or as opportunities to extend the choice and number of activities in which people are engaged.

For urban transportation projects, travel time savings form by far the greatest portion of total "tangible" project benefits to users, being generally around 50% or higher than the savings for rural and inter-urban transport projects. It is therefore of considerable importance that the values of time saving used in project planning and evaluation are well based in their theory and methods of estimation.

The objectives of this project were *"... the validation and/or refinement of the travel time values used in the Transit New Zealand Project Evaluation Manual 1991. ..."* The project was therefore primarily concerned with the role of VTTS in the evaluation context rather than with its role in the estimation of travel demand. However both sides of the issue are inter-related, and are covered in this report.

1.2 Definition of a "Value Of Travel Time Savings"

Three distinct VTTS can be defined:

- resource values,
- behavioural values, and
- equity values.

(A further distinction can be made between behavioural values and social values, but it is not discussed here.)

1.2.1 Resource Values

The project is principally concerned with establishing VTTS appropriate to public sector economic evaluation of road transport projects. This value (or values) is referred to as the *resource* value of travel time savings and is the amount of money that *society* is willing to pay to "save" a unit of travel time. (Although "saving" travel time is really a shorthand description for transferring time between travel and another activity or activities.)

1.2.2 Behavioural Values

The *behavioural* VTTS will normally differ from the *resource* VTTS. Behavioural values are those values which, in combination with other choice factors, best describe an individual's decision to travel in any particular circumstances, and are the appropriate values for travel demand modelling. They approximate an individual's "willingness-to-pay" (WTP) VTTS. Behavioural values can differ from resource values because travellers are either not faced with, or misperceive, costs when faced with travel decisions.

However, behavioural VTTS provide a basis from which resource values can be inferred. Empirical studies to establish behavioural VTTS have formed the basis for the values used in social cost benefit analysis in several overseas countries, and this practice has been followed by New Zealand.

An exception is the treatment of travel for work or business purposes: in this case historically the VTTS has been estimated from the marginal productivity of labour (MPL), although behavioural VTTS has also been used as a comparison. This approach in its crudest form assumes that time saved in work/business travel is transferred in its entirety to production at the workplace, and that the value to the employer on average is the marginal value of production.

A rational employer can be expected to employ labour up to the point at which the total costs of employment equate with the value of production. Hence the value of working travel time is estimated as the gross wage plus employer's on-costs. This approach makes questionable assumptions regarding the transfer of travel time to other purposes, neglects possible productive use of in-travel time, and ignores the utility to the employee of time spent at work or in travel. Hensher (1989) provides a more extensive formulation of this approach, which is discussed in Appendix 6 to this report.

1.2.3 Equity Values

The concept of an *equity* VTTS has arisen through what is essentially an overlay of other political objectives other than economic efficiency. The main example is the practice of the Department of Transport (DoT) in the UK which has averaged out differences in the WTP values over different income groups and for different transport modes. Equity values are discussed in Appendix 9 of this report.

1.3 Scope of Project

The project involved the following tasks:

1: Review of Previous Work and Application
2: Further Work
    2.1: Development of Further Work Programme and Priorities
    2.2: Interim Report
3: Preparation of Workshop on Future Directions
4: Preparation of Final Report.

The purpose of Task 1, i.e. the principal project task, was to review recent international research findings and information on how these are being practically applied. It concentrates particularly on work which has been carried out subsequent to the last comprehensive review of the subject in New Zealand, which was in 1986/87 for the Urban Transport Council (UTC). This task was intended to consider the potential application of international research to the New Zealand situation and to identify weaknesses or deficiencies either in the research base as a whole, or in its applicability to the local New Zealand context.

From the Task 1 review, Task 2.1 involved the development of an outline programme of further research work on VTTS, directed at refinement of the travel time values used in the 1991 Transit New Zealand Project Evaluation Manual (PEM). The Interim Report (Task 2.2) then summarised the findings from Tasks 1 and 2.1.

Task 3 involved holding a Workshop for Transit New Zealand and other participants to review the Interim Report findings with the consultants and in particular to discuss and refine the suggested programme of further research.

Following the Workshop, the views expressed were reviewed by the consultants and the Interim Report was revised and expanded to form this Final Report, as Task 4.

1.4 Structure of This Report

This report is set out in three further sections:

- Section 2 provides an overview of recent international and New Zealand research on VTTS and provides a summary of the basis of the time values currently used in the Transit New Zealand Project Evaluation Manual (PEM).
- Section 3 identifies the state of knowledge and the principal areas of uncertainty in knowledge of VTTS, categorised into theoretical basis, empirical behavioural studies, transferability of results, and practical application.
- Section 4 summarises the principal areas of weakness identified with the present PEM values, in the light of the international evidence. It sets out an outline research programme and priorities to address the areas of weakness where it is anticipated that further research would be most cost-effective.

The individual issues identified in relation to VTTS are discussed in detail in a number (18) of appendices, as listed on the contents page.

2. BRIEF HISTORY & DEVELOPMENT OF VALUATION OF TRAVEL TIME SAVINGS

2.1 International Developments

The following is a brief history of VTTS research and its application in the United Kingdom (UK), United States of America (USA), Australia, and the Netherlands. Appendix 8 discusses some of the findings of recent empirical research in more detail.

2.1.1 United Kingdom

In the UK, which has the largest body of research on the subject, monetary values have been placed on travel time savings going back to at least 1960. A landmark paper on the subject was published by Beesley (1965). In 1967 the principle of using explicit VTTS in project evaluation was established by the UK Ministry of Transport (MoT), and this had been consolidated by 1970 (Harrison and Quarmby 1969). On the basis of empirical evidence, the value for non-working time was set at 25% of the average gross wage rate (AGWR); and for work travel time savings the MPL approach was accepted, i.e. the gross wage rate plus employers' on-costs for working travel time savings. This basis was maintained largely unchanged by the UK Departments of the Environment (DoE) and Transport (DoT) through the 1970s and 1980s for use in economic evaluation of road schemes, implemented in the main through the DoT COBA procedures and with unit values indexed from year to year.

In the early 1980s, it was becoming apparent that non-working time was probably being undervalued and a major, new research effort was sponsored by the UK DoT. This research was carried out over a five year period in the early to mid-1980s by the MVA Consultancy, the Transport Studies Unit at Oxford University and the Institute of Transport Studies, Leeds University. This was one of the most intensive investigations into the subject for many years and culminated in the MVA et al. (1987) report to DoT and the subsequent adoption of new values for project evaluation.

In the new guidelines, the MPL approach was retained for working time but non-working time values were increased to 40% of the mileage-weighted hourly earnings of commuters. Not all the research findings were translated into project evaluation practice. In particular the differences between modal values were passed over on the grounds of equity, simplicity, and the difficulty of providing advice on modal values that are not location-specific. However, the finding which indicated that persons with fewer time constraints (such as students and the retired) exhibited lower VTTS than the full-time employed population, was carried through into project evaluation in cases where the former groups form an important component of the evaluation context.

The methodology and results of the UK studies have been previously summarised in reports to the NZ UTC (Urban Transport Council) and to Transit New Zealand (Beca 1987, 1992).

2.1.2 United States of America

The use of cost benefit analysis in transportation planning in the USA was originally rare, even though the USA was a leader in the use of the method for other sectors. Advice on VTTS was provided in the AASHTO (1977) "Red Book" on project evaluation: it comprised the results of a collection of studies but did not give firm prescriptive guidelines on application. The advice was based on Lisco (1967), Thomas (1967), and Thomas & Thompson (1970, 1971). The latter studies produced non-linear relationships between the value of time and amount of time saved, and this has been a continuing point of contention in the acceptance of the AASHTO advice. The second edition of the AASHTO manual continued without substantial modification. The third edition is expected to contain substantial changes in recommended values for VTTS.

2.1.3 Australia

The recent history of VTTS research in Australia is well summarised in Hensher (1989), who has been personally responsible for much of the Australian–based research on the topic. He introduced scientific rigour into Australian studies of VTTS in the early 1970s, publishing a comprehensive review of the earlier history of empirical research in 1976 (Hensher 1976).

A review by the Bureau of Transport Economics (BTE 1982) includes information from as early as 1968. At this time the VTTS adopted by the Commonwealth Bureau of Roads (CBR) for national highways was an unusually low 13% of the wage rate, although this was not based on any empirical study. Subsequent studies saw a progressive rise in the non-work VTTS as a proportion of the wage rate, although practice appears to have lagged on the results of empirical research.

As Australia has the benefit of these empirical studies, and is a close neighbour to New Zealand with similar levels of car ownership, public transport usage, urban densities and similar social organisation, the Australian VTTS findings should probably be accorded considerable weight.

2.1.4 Netherlands

Following on the UK DoT study, the Hague Consulting Group (with some common membership with the UK project team) carried out a series of stated and revealed preference studies in the Netherlands for the Dutch Ministry of Transport and Public Works. These studies have been reviewed in Bradley and Gunn (1990, 1991). The procedures used were *"designed to be flexible, so that average values can be produced for virtually any sample and categorisation of interest, and can also be applied to reflect future scenarios."*

Because of the experience and standing of the team members, this research should receive particular study when considering a programme of investigation for New Zealand.

The Netherlands study results generally confirm the factors of variation in VTTS found in the preceding UK studies, in that VTTS:

- increases with, but at a lesser rate than, income;
- is lower for those not in formal full time employment;
- is higher for those with less "free time" in the week;
- is higher for congested traffic conditions; and
- is lower for bus travel than for private car.

Other features of interest are:

- higher values for young commuters and business travellers compared with the bulk of the population;
- higher values for single person/worker households for commuting and business travel purposes; and
- lower values for female work commuters than for males.

2.2 New Zealand Developments

2.2.1 Ministry of Works & National Roads Board

The use of social cost benefit analysis in the evaluation of roading projects in New Zealand goes back at least to the mid-1960s, when evaluation was carried out by the National Roads Board (NRB). VTTS 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 by its Circular Memoranda 90 and 98 (Bone 1980).

Cox (1983) provided the next comprehensive review of the methodology and practice of VTTS, again based on international research. Time values for economic evaluation were established using the MPL approach for working time and based on 25% of the wage rate for non-working time. These values were indexed from year to year (described in Brown Copeland & Co. 1982). This basic method was continued in an NRB Roading Division Memorandum RD144 (the successor to Circular Memorandum 98), and then into the NRB Technical Recommendation TR9, "The Economic Appraisal of Road Improvement Projects" (Bone 1986).

2.2.2 Urban Transport Council

In 1986 the New Zealand UTC commissioned research aimed at providing a matrix of travel time values for different trip purposes and travel modes, to review and extend the procedures and methods in use at that time. This project resulted in three outputs:

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

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

2.2.3 Transit New Zealand

On its inception, Transit New Zealand (TNZ) adopted the National Roads Board standards and procedural guides, but has subsequently continued to progressively update and review them on the basis of changing circumstances, public perceptions and technical knowledge.

In 1989 it sponsored a visit to New Zealand by Dr Ted Miller of the USA 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 international data. The recommendations were not immediately put into effect.

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

2.3 Current PEM VTTS & Their Basis

The basis of the present VTTS contained in the PEM is described and the discussion has been adapted from Beca (1992). The 1991 values, as given in the PEM, are shown as facsimile tables in Figure 2.1.

2.3.1 Work Travel

The present calculation of VTTS during working time is based on Cox (1983). The MPL approach is used, which means that VTTS is estimated as the gross hourly wage rate plus any employment-related on-costs borne by the employer.

The data required to calculate the MPL are:

- average hourly gross wage rates, for the range of occupational groups;
- information on employment-related on-costs for each occupational group, which include: accident compensation (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.

Figure 2.1 Facsimile of Tables in Appendix A3 of PEM

(p.A3-1 from TNZ 1991)

TRAVEL TIME VALUES

A3.1 INTRODUCTION

Unit values of vehicle occupant and vehicle travel time costs are given in this appendix. Separate values are given for work and non-work trip purpose. Work trip purpose comprises travel during the course of paid employment; it does not include travel to and from work.

In Table A3.1 separate values are given for vehicle drivers and for vehicle passengers as well as separate values for standing bus passengers as opposed to seated bus passengers. In Table A3.2 the values for vehicle and freight time are combined. In Table A3.3 for Standard Traffic Mixes the values for occupant time, vehicle time and freight time are combined for different types of road and for different time periods.

TABLE A3.1
BASE VALUES FOR VEHICLE OCCUPANT TIME COSTS in Dollars/Hour (1991)

Vehicle Occupant	Work Travel Purpose $/hr	Non-Work Travel Purpose $/hr
Car, Motorcycle Driver	19.0	6.1
Car, Motorcycle Passenger	19.0	4.6
Light Commercial Driver	17.2	6.1
Light Commercial Passenger	17.2	4.6
Medium Commercial Driver	14.1	6.1
Medium Commercial Passenger	14.1	4.6
Heavy Commercial Driver	14.1	6.1
Heavy Commercial Passenger	14.1	4.6
Seated Bus Passengers	19.0	3.8
Standing Bus Passengers	19.0	7.7
Pedestrian and Cyclist	19.0	9.2

TABLE A3.2
BASE VALUES FOR VEHICLE AND FREIGHT TIME COSTS in Dollars/Hour (1991)

Vehicle Type	Cost per Hour
Passenger car	0.4
Light Commercial Vehicle	1.4
Medium Commercial Vehicle	4.8
Heavy Commercial Vehicle I	13.9
Heavy Commercial Vehicle II	22.7
Bus	0.0

Figure 2.1 (continued) **Facsimile of Tables in Appendix A3 of PEM**
(p. A3-2 from TNZ 1991)

TABLE A3.3
TRAVEL TIME COST FOR STANDARD TRAFFIC MIXES:
OCCUPANT TIME, VEHICLE TIME AND FREIGHT TIME COMBINED.

ROAD TYPE AND TIME PERIOD	$/h 1 July 1991
URBAN ARTERIAL:	
Morning Commuter Peak	12.3
Daytime Inter-Peak	15.8
Afternoon Commuter Peak	12.3
Evening/Night-time	13.2
Weekday All Periods	14.4
Weekend/Holiday	11.7
All Periods	13.7
URBAN INDUSTRIAL:	
Weekday	17.5
Weekend/Holiday	14.0
All Periods	16.7
URBAN OTHER:	
Weekday	13.5
Weekend/Holiday	11.1
All Periods	13.0
RURAL STRATEGIC:	
Weekday	21.2
Weekend/Holiday	16.5
All Periods	18.9
RURAL OTHER:	
Weekday	20.8
Weekend/Holiday	16.0
All Periods	18.5

In 1978, the main source of data was the latest half-year employment survey for gross wages (Supplementary Tables to the Labour and Employment Gazette; NZ Labour Department). Additions for employment-related costs were estimated approximately, with the recommendation that these costs are studied in more detail. However this recommendation 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 intended to be the subject of further study.

The 1991 revised values basically follow the same method of calculation. Information sources are the 1989/90 Household Incomes and Expenditure Survey, the Monthly Abstract of Statistics which gives wage rate indices and the Quarterly Survey of Employment, February 1990 figures (produced by Department of Statistics). The index data were projected forward to the July 1991 base date.

A number of assumptions were involved in the calculations, which were not possible to check when the PEM was being produced. These include the distribution of occupational categories (mileage-weighted) in the driving-for-work population, particularly for car and light commercial vehicles; and the on-cost rates, for which an attempt has been made to improve on the estimates but which require further work.

No attempt has been made so far in New Zealand to identify the proportion of working travel time devoted to leisure, the proportion of in-travel time used for work activity and its relative 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 PEM was that international empirical research has in general yielded values of work travel time of similar magnitude to the MPL value without any of these adjustments. Therefore a decision was made to retain the existing method for the time being.

2.3.2 Non-Work Travel Time

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

2.3.3 Base VTTS for Car Drivers

The base VTTS other than for work/business purposes was set for a car driver from an average income household travelling in free-flowing traffic to full-time paid work. The behavioural value adopted, after consideration of the international 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%, which represents 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 therefore required, and further work on this topic was foreshadowed.

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) for New Zealand.

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

2.3.4 Car Passengers

VTTS for car passengers and for 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 on the work of 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 fewer 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 PEM was a 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 should be the same, the weight of studies seemed to indicate that VTTS for car passengers would generally be higher than that for urban bus passengers, even when income effects were excluded.

2.3.5 Bus Passengers

The recommended VTTS for seated urban bus passengers was 25% of the wage rate, which is 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 it is considerably less than the results of that study which indicated a VTTS for bus passengers about 50% of that of car drivers. For express bus services, a higher value would be expected, and an equal value to car passengers would seem reasonable.

2.3.6 Walking and Waiting for Transport

The PEM does not distinguish between walking to access public transport and walking as the main mode, and it does not address waiting time for public transport. The background working paper (Beca 1992) did, however, consider this issue, recommending a single value for walking and waiting time for public transport access equal to 1.5 times the VTTS for car drivers. This was a similar relativity that was given by the values recommended by Miller (1989), and equates 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 inadequate.

2.3.7 Trip Purpose

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

2.3.8 Modifying Factors for Traffic Congestion and Reliability

Good evidence that time savings in congested traffic are valued more highly than in free-flowing conditions was found. However how much the differences resulted from uncertainty and how much from driver stress and frustration from the road conditions was unclear.

Reflecting the benefit of increased reliability of travel in project evaluation was seen as desirable, so that transport improvements that achieve such benefits are valued, even though they may not result in overall time savings.

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

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

2.3.9 Modifying Factors for Comfort

The evidence on which to determine any modifying factors for levels of in-vehicle comfort was found to be limited. However a main discriminating factor suggested was whether passengers have to sit or stand. The base values assume fully seated passengers. For standing passengers Miller (1989), on the basis of Algers et al. (1991), had recommended a VTTS of 250% of the wage rate, or six times his base passenger value. This very high value was not applied in the PEM. Instead for urban bus travel, a value for standing passengers of 2.0 times the seated in-vehicle time value, that is 50% of the wage rate, was recommended.

2.3.10 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 PEM.

2.3.11 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 issue was questioned from time to time, and was considered in the preparation of the PEM. Again, the conclusion was reached that this effect was likely to be very small and no allowance was in fact made in the 1991 issue, although it was suggested that the matter should receive some further study.

2.4 Treatment of Public Transport in PEM

At present, the PEM deals only in a very partial and cursory fashion with methods and parameters for evaluating public transport investment improvements. It includes values of time related to seated and standing passengers, values which are of use in evaluating road improvement projects. No specific information is given on public transport access (waiting and walking) time functions, interchange time functions or public transport operating cost functions.

The evaluation of public transport projects would be better dealt with in a separate manual, which would need to be prepared. On this basis, the specific needs of public transport project evaluation have not been considered in developing research proposals for VTTS (although some of the research projects proposed may be able to cover VTTS for public transport travel).

3. STATE OF KNOWLEDGE & PRINCIPAL AREAS OF UNCERTAINTY

3.1 General

Areas of uncertainty in relation to VTTS can be broadly categorised as follows:

- Theoretical basis (S3.2)
- Methods and findings from behavioural studies (S3.3)
- Transferability of international research (S3.4)
- Practical application for project planning and evaluation (S3.5).

Uncertainty in each of these areas, either in the international research base or in its application to New Zealand road project planning and evaluation, are discussed. Several of the topics raised are reviewed in more detail in the appendices to this report.

3.2 Theoretical Basis

The theoretical basis for a monetary VTTS relies on the microeconomic theory of the consumer and the integration of the time duration of consumption into this theory. Developments in the theoretical base have allowed suggestions for estimating VTTS under a variety of constraints, which can then be compared with empirically derived results. This theoretical basis also has a role in determining the adjustments that need to be made to "behavioural" values of time to provide appropriate VTTS for project evaluation.

3.2.1 Restatement of the Microeconomic Theory (Appendix 17)
The basis of microeconomic theory (described in Appendix 17.2) is that the consumer maximises his/her utility (the satisfaction deriving from consumption activities) subject to various constraints. The basic theory originally ignored the fact that there is a time requirement for consumption, and that for some activities this time requirement will be fixed, while for others there will be a minimum time requirement. Introducing the time duration of consumption into modelling theory provides a mathematical basis for the value of time transfers between activities.

The current consensus on a mathematical specification of the utility maximising behaviour of the consumer, taking account of time duration of consumption and time constraints, appears to lie with models of a form first proposed by DeSerpa (1971), developed by Bruzelius (1979) and later by MVA et al. (1987), as follows:

Maximise $U(x,t,t_w)$ subject to constraints (i) to (iv):

(i) $p.x - w.t_w - I \leq 0$ (income constraint) [λ]

(ii) $\sum t_i + t_w - T = 0$ (time constraint) [μ]

(iii) $t_i > t_i^*$ (activities with minimum times) [ι_i]

(iv) $t_i = t_i^*$ (activities with fixed times)

(v) $t_w > t_w^*$ (minimum work time constraint) [ϕ]

where $U(x,t,t_w)$ is the total utility,
I is the total income,
T is the total time available, and
* denotes a minimum allowable value.
p = price

This specification therefore envisages that some activities have fixed consumption times (constraint iv), and some have minimum times (constraint iii). The total time for all consumption activities plus work must equal the total time available (constraint ii). There is in fact no need to specify constraint (iv) as these activities can be subtracted from T to give a modified total time budget.

The marginal utility of relaxing these constraints, indicated against each of the above that are in [ ], are:

λ marginal utility of additional income
μ marginal utility of increased total time
ϕ marginal utility of decreasing minimum work hours
ψ_i marginal utility of decreasing the time requirements for activity i.

It follows that first order conditions for optimality are:

(1) $(1/\lambda).\partial U/\partial x_i = p_i$ the marginal value of consuming good i is equal to its price (p_i).

(2) $(1/\lambda).\partial U/\partial t_i = \mu/\lambda - \iota_i/\lambda$ the marginal value of time spent consuming good i is the difference between the marginal utility of increasing the total time budget less the marginal value of decreasing the minimum time constraint on activity i.

(3) $(1/\lambda).\partial U/\partial t_w = -w - \phi/\lambda + \mu/\lambda$

the marginal disutility of work (U) is compensated by the wage rate (w) plus the marginal value of decreasing minimum working hours (ϕ) less the marginal utility of increasing the time budget (μ).

The value of transferring time from work to another activity can be obtained from the second and third of these conditions as:

$$(1/\lambda)(\partial U/\partial t_i - \partial U/\partial t_w) = w + \phi/\lambda - \iota_i/\lambda$$

The value of saving work time, to the employee, is therefore the after-tax wage rate *only* if there is no minimum time constraint on working hours ($\phi = 0$) and no time constraint on the substituting activity ($\iota_i = 0$).

Returning to the second condition above, where the value of time is transferred between two activities *i* and *j*, then the value is given by:

$$\psi_j / \lambda - \psi_i / \lambda$$

This means the value of transferring time depends on whether there are binding time constraints on the activity from which time is being transferred (such as travel) and the activity that time is being transferred to. If the activity which time is being transferred to is leisure, then the value of transferring time is ψ_j / λ, and this is generally the intention when the term "value of travel time" is used in transport appraisal.

If there is no minimum time constraint on activity *j*, then $\psi_j = 0$, and the value of time spent in activity *j* is μ / λ, i.e. the rate of commodity substitution between income and time, or the WTP to increase the time budget. (This is sometimes referred to as the resource value of time, not to be confused with shadow pricing of behavioural VTTS to obtain a resource value.) It follows that if $\psi_j = 0$, then activity *j* is a pure leisure activity. Transferring time from one such leisure activity to another has no value, as the value for both activities is μ / λ.

If the situation being studied is a time transfer between a travel activity and an activity without a binding time constraint, then ψ_i / λ can take a range of values, depending on the marginal utility of the travel activity:

- If travel has a marginal disutility, which is the most common case, then the value of transferring time from travel to the other activity will be greater than μ / λ ($\psi_i > \mu$).
- If travel has some positive marginal utility, the value of transferring time may still be positive, provided this utility is less than the resource value ($\mu > \psi_i > 0$).
- If travel has no binding time constraint, then it is by definition a leisure activity, and there is no value in transferring the time to another leisure activity.

3.2.2 Non-Linearity in VTTS (Appendix 1)

The question of linearity of VTTS for very small, moderate and large values of time savings, and depending on the context in which these savings occur, has long been a vexed question, and an area in which many attacks have been launched on the integrity of VTTS in project evaluation. This has historically formed a point of difference between practice in the USA and other countries, with the incorporation of research findings of Thomas & Thompson (1970, 1971) in the AASHTO Manual (1977). The update of the AASHTO Red Book appears likely (as at the time of writing) to remove this point of difference.

The conventional wisdom on linearity is that to treat time savings as non-linear would introduce inconsistencies and practical difficulties to project evaluation, as the combined effects of staged developments would no longer be additive. Project evaluation deals with systematic changes to the transport system in the medium term, assuming that people have a chance to adjust. This behaviour may well differ from short-term responses to small and possibly short-lived time savings, which may not be perceived by the traveller.

However concern about the issue of non-linearity and the valuation of small savings still remains. For example, often doubts are expressed that small travel time savings can be used effectively in long-distance trucking operations. Another concern is that there may be a period of adjustment to a new transport facility, over which time savings gradually become more effectively employed. This whole question is bound up with habitual behaviour and thresholds required to initiate behavioural change. Such changes may be made as step functions rather than as a smooth continuous response.

On this issue our conclusions are that, for practical application to project evaluation over the medium to long term, values of travel time should be treated as linear with respect to the amount of time saved, even though empirical studies may indicate some non-linearity for small time savings over the short term.

Some evidence indicates that VTTS may be non-linear against trip length, arising from the degree of discomfort associated with the travel mode, i.e. for long trips fatigue may increase more than proportionately with the travel time. However, such differences should be capable of resolution by assigning different VTTS to classes of travel, such as urban versus rural, or local versus inter-urban.

An investigation of non-linearity could be included within one or more of the empirical studies suggested in the research programme proposed in Section 4. However, it is doubtful whether this issue should be given a high priority.

3.2.3 Effects of Congestion and Unpredictability of Travel Times (Appendix 2)
The UK research project (MVA et al. 1987) indicated that reliability of travel time and arrival time were both likely to be important determinants of VTTS even though that research had not specifically included reliability in the experimental design. Subsequent studies confirm this view and it appears that in some circumstances the value of providing certainty in journey duration may be considerably greater than that of reducing journey time (Senna 1991).

The reliability of travel time is closely connected with traffic congestion. The evidence is that the discomfort, stress and frustration of travelling in a heavy traffic stream increases the disutility of the time spent in travel as well as contributing to uncertainty in arrival time.

Recent research also indicates that reliability effects are likely to be non-linear with respect to the variability of journey time. Small variations about the expected time will have a small value compared to large variations.

While this issue is one which will no doubt continue to be investigated internationally, if any empirical studies of VTTS are to be undertaken in New Zealand then it will be important that they include reliability and congestion effects. Indeed, this could be one of the more important and yet less researched aspects of the subject.

3.2.4 Taxation Treatment (Appendix 3)

The treatment of taxation in the application of VTTS has given rise to debate over the years. The accepted convention is that, for non-working time, the conversion from behavioural to resource value of time savings is obtained by dividing the behavioural value by $(1 + r)$, where r is the effective rate of indirect taxation on consumer goods and services.

This approach is supported by the argument that behavioural values are derived from people's willingness to trade time for money that would otherwise be spent on goods that carry indirect taxation. The real resource for which the time is being traded is therefore equal to the expenditure less the indirect taxation component.

3.2.5 Compatibility of Travel Time and Accident Valuation Approaches (Appendix 4)

Miller (1989) has argued that, for a balanced evaluation process, the WTP values for saving a statistical life and the VTTS must maintain an appropriate relativity. Although there appears to be a wide margin of uncertainty, the value of life may be relatively too high (or the value of travel time relatively too low) in the present PEM. One particular point which needs to be settled is the apparently inconsistent treatment of indirect taxation in converting from behaviourally derived WTP values to resource values for time and life.

3.3 Methods and Findings from Behavioural Studies

Apart from the speed choice study discussed by Guria & Miller (1991) which was aimed primarily at the WTP value of statistical life, no empirical studies have been carried out in New Zealand designed specifically to elicit behavioural VTTS. New Zealand evaluation practice is thus based almost entirely on a simple transfer of international findings, using a percentage of the average wage rate (AWR) as the means of setting a value. The acceptability of this method depends on careful selection and interpretation of international study results, and it can by no means be considered desirable to perpetuate reliance on such a process.

However, before embarking on empirical research in New Zealand, the successes and weaknesses of international studies need to be reviewed, so that any such research starts from an informed basis, and with a full understanding of the practicalities and costs involved.

3.3.1 Methodologies for Behavioural Studies (Appendix 5)

From studies over the last 10 years or so, stated preference (SP) methodologies have moved from being regarded as rather suspect to being the preferred method for experimental studies of traveller preference. This advancement has been achieved by convincing back-to-back revealed preference (RP) and SP studies, which have provided confidence that well designed SP experiments can elicit realistic measures of traveller preference. With this confidence established, the increased control possible in a SP study compared with RP methods, the ability to explore preferences not accessible to RP methods, and the generally higher statistical significance of the results, have all contributed to adoption of this method of approach. SP experiments also offer the advantage of relatively cheap survey application methods, such as the postal return questionnaires used in the Netherlands studies (reported in Bradley & Gunn 1990, 1991).

The development of microeconomic utility theory to incorporate the time duration of consumption and the compatibility of random utility-maximising models of travel choice with this theory have made the theoretical basis of study methodologies more robust.

3.3.2 Opportunities for Behavioural Studies in New Zealand (Appendix 5, 16)

In the New Zealand situation, the opportunity for RP experimental studies is largely limited to a few situations of modal choice and one or two route choice options. Speed choice can be considered a further possibility, given that the trade-offs between time, perceived vehicle operating costs and perceived risk of accidents can be effectively defined. RP study possibilities include:

- urban bus versus car in the main centres,
- a three way study of choice between suburban rail, bus and car in Wellington and, less probably, in Auckland,
- ferry versus bus and possibly car in Auckland,
- toll bridge versus untolled route choice in Tauranga.

A possible survey data base for RP studies already exists in Wellington through the GATS (Greater Wellington Area Transport Study) study, in Dunedin, and from recent studies in Auckland and Christchurch. These studies have used disaggregate models of generalised cost in which the travel choice factors, including time, are identifiable. However, the extent to which these studies can be used to give information on the VTTS from the coefficients against travel time will depend very much on the nature of the data collected and how the models have been specified.

Because of the limited expectations from RP studies, judging from international experience, and the limited travel choice situations which they cover (primarily modal choice, involving all the self-selectivity problems and unique modal features of the urban centres in which each study is made), a series of SP studies specifically targeted at eliciting VTTS may be considered. These studies should be of travel contexts similar to those which commonly occur in road project evaluation. Studies should target in particular car travel on rural highways and shorter distance urban journeys, probably involving route or speed choice and also taking account of congestion and reliability of travel time.

Mode choice studies based in the main urban centres, while of interest for urban transport planning, are likely to yield VTTS which are somewhat specific to the travel choices being investigated and may not be applicable to the general run of road project evaluation.

Suggestions for possible studies are made in Section 4 and Appendix 5.

3.3.3 Valuation of Working Time (Appendix 6)
In the PEM, the MPL approach has been implemented in a fairly simplistic manner. No corrections have been made for the proportion of travel time diverted to productive work, therefore tacitly assuming that all travel time saving is productively employed. No correction has been made for productive use of travel time and the relative productivity of this time compared to time at the work site. The implication is that none of the travel time is usefully employed. Allowance for both of these factors will tend to reduce the value of time savings to the employer.

On the other hand, the preferences of the working traveller for time spent travelling versus time spent at the work site are also not addressed. If travelling is preferred then this will again depress the VTTS of in-work travel time.

The current approach also assumes that working hours are paid at an equal rate. For many travellers in the self-employed and professional categories, a proportion of in-work travel (not commuting) is undertaken out of business hours for which no additional remuneration is paid. In general, working hours have become more flexible, and this demands a reappraisal of whether the MPL approach is still tenable or of how it can be modified.

Further weaknesses are apparent in the information used in the PEM on employer on-costs of labour. The amounts being paid in allowances, payments in kind and the administrative costs of employees are not well established. Costs currently in use either are based on very dated information or are little better than guesstimates. Hours of work are not well defined, so that both the nominal and the effective hours of work are required, to adequately convert between annual and hourly rates of pay and employers' costs.

Weaknesses are also found in the information on the occupational categories and incomes of working travellers and how the mix of occupations differs by road type and time of day. The present values again date back to assumptions about in-work traveller occupations from 15 to 20 years ago which, even then, were probably not very well established.

This review concludes that three main aspects would benefit from specific research in the New Zealand context:

- Investigation of the extent to which savings in business travel time will result in increased work production, and/or reduced employer costs, and the extent to which the savings will result in increased leisure time. These effects might be expected to differ by transport mode and by time of day.

- Research into average hourly labour rates and labour on-cost proportions for different industry sectors/employee types.

- Research into the income levels of people who travel on business (by industry sector, etc.) and their proportional representation in the traffic stream. Again this will vary by mode, time of day, etc. (refer also Section 3.5.3 and Appendix 15).

In all three of these issues, the effect on the VTTS is expected to be somewhat specific to New Zealand work practices and activity schedules. Therefore only limited reliance can be placed on international research results and the need is evident for empirical investigation based in New Zealand. Appendix 6 also deals with this topic.

3.3.4 VTTS Relating to Commercial Vehicles (Appendix 7)
Currently no allowance for freight values of time in the composite vehicle plus freight time values is made in the PEM (although this is not acknowledged). Some modest interim values have been suggested in Beca (1992), but on the basis of fairly limited information. The literature on this topic appears quite small and of variable quality.

The value of freight time can be related to the inventory holding value of the goods, which in most cases will be small for the short periods involved, to the perishability of the goods, and to any costs of maintaining the integrity of the goods in transit, such as refrigeration costs. To effectively address this topic requires a study of these costs, which should be a quite straightforward exercise.

The literature review shows a paucity of information on the subject of the value of freight time, and the conclusions that have been reached show considerable variation. Freight time may be valued because of the costs of deterioration in transit, which in turn are related to perishability, packaging and environmental control, and the roughness of movement. It also may be valued because of just-in-time production and inventory practice in the distribution chain, which puts high value on reliability of transit time. (Reliability is also discussed in S3.2.3.) At least for road transport, reliability of freight transit cannot be traded against additional holding costs. Thus there is reason for undertaking specific research to identify the cost trade-offs between reliability costs, in-transit cost losses, and additional inventory costs. However, against this the evidence tends to suggest that goods transit costs are small in relation to the costs of vehicle and driver.

The present PEM allows for savings in vehicle ownership costs for commercial vehicles and business/commercial cars (including taxis) resulting from time savings, but makes no allowance in the case of buses. The cost allowances are based on the annual standing charges divided by average annual hourly utilisation. This effectively assumes that commercial vehicle fleets will be reduced (pro rata) as a result of time savings. Our appraisal suggests that the present PEM assumptions should be reviewed for :

- goods vehicles, to review whether the assumption of pro rata vehicle savings is reasonable;
- buses, to review whether some allowance should be made for vehicle savings.

3.3.5 Evidence on Behavioural VTTS (Appendix 8)
The finding that VTTS increases with income, but at a less than proportionate rate, appears to be well established. However, as the difference appears relatively small over most of the income range, it may not be necessary to separately identify income groups when applying values of time in practical cases.

Self-selectivity effects and the differing attributes of public transport modes make it difficult to transfer the results of empirical studies involving mode choice to other geographic locations.

The behavioural VTTS for work commuting car drivers is a likely "base value" against which the relative VTTS for other travel contexts can be prescribed in terms of percentage differences, using the Netherlands study (Bradley & Gunn 1990, 1991) as a model. Using the AWR, the basis for this value currently leaves a considerable range of uncertainty, of between 30% and 70% of the AWR. The value currently recommended in the PEM is nominally 46% (behavioural), but empirical studies based on New Zealand conditions are desirable to confirm or modify this finding.

International evidence is that commuters generally value their time savings more highly than do people on other (non-business) trips. This difference is not recognised in the present PEM values, but would warrant further investigation in any New Zealand studies.

The correct interpretation of car driver VTTS to arrive at an appropriate resource VTTS for all the car occupants is rather unclear and any New Zealand-based study should consider this question in the study design.

Any New Zealand study should also endeavour to compare VTTS for long distance car travel with local urban area travel.

Variations in VTTS with person type which can be ascribed mainly to time scheduling constraints are significant, and these variations should be recognised when establishing VTTS for evaluation purposes.

3.3.6 Equity Issues (Appendix 9)
Any departure from WTP VTTS for use in the evaluation of public projects, other than to correct for traveller misperceptions, must be regarded as a departure from consumer surplus principles on which social cost benefit analysis of road projects is ostensibly based. In the past, such departures could be rationalised by the rather sparse information on differentiating factors which made anything other than an "average" value difficult to justify. However, this comfortable excuse is no longer valid.

Consequently, if income or any other differentiating factor is to be knowingly ignored, then there should be an explicit and agreed reason for doing so, as the result is potentially to penalise some otherwise "worthy" projects and elevate others that are less deserving. It means that objectives other than economic efficiency are being introduced, implying that one of the basic tenets of cost benefit analysis, namely that there is an optimal distribution of incomes, is not being met and that transport investment is being used as a tool of social policy. It is obvious that no conscious analysis has been made of the effects of applying an "equity" VTTS to the development of transport infrastructure and services.

The ultimate decision is inherently political, so any further investigation of this topic should more clearly identify the possible effects in terms of transport project selection between applying WTP values and an "equity" value. There are practical advantages in reducing the complexity of the analysis if equity values are used, and there is a limit to the degree of dissagregation that can practically be handled. These considerations should also be taken into account when recommending a course of action.

3.3.7 VTTS for "Slow" Transport Modes (Appendix 10)
A few specific gaps exist in the VTTS advised in the PEM for certain modes of transport which have been given little attention:

- pedestrians (walking as the main transport mode),
- cyclists,
- trains and ferries.

Studies which include walking time savings invariably consider pedestrian movement only as an access mode to either public transport or car. No studies have been identified which deal with walking as a principal mode. However available evidence suggests that self-selectivity effects will result in lower VTTS for people walking (as main mode) relative to those accessing public transport access, and that these values in turn will be lower than those for access to car parking.

Again, for cyclists, a shortage of empirical research exists. However the self-selectivity argument would lead to an expectation that the VTTS to cyclists will generally be lower than for motorised transport. This is dependent of course that average journey speed is lower than for other available modal choices (which could conceivably exclude private car).

Our judgement is that the need for empirical study of walking and cycling in New Zealand is of lower priority than other possible research issues, because results from studies in other countries can be applied to New Zealand.

3.4 Transferability Of International Research

Given that now a large body of international research on VTTS exists, and given the relative paucity of empirical studies in New Zealand, there is and will continue to be a demand for the transfer of international research results for use in New Zealand. In the past this has been done in a fairly rudimentary way by:

- Adopting the MPL approach for work time savings, and carrying out a minimum of investigation of employers' costs and working traveller wage rates and occupations.
- Taking a percentage of the AWR as the value of non-working time. This percentage is obtained by converting international research results into percentages of the wage rate in the source country, and then taking some typical value over the country and study results considered to be the most reliable, or the most similar in some way to New Zealand.

There are uncertainties both in the way in which research results are transferred and in the way they have been implemented in New Zealand. While the AWR is a useful basis on which to convert values from international practice, this basis can only be regarded as a convenience as there is no direct connection between AWR and VTTS.

A more considered comparison would probably require an understanding of the direct and indirect taxation regimes in the source countries when the studies were carried out, the disposition of income on transport versus other household expenditures, the travel time budgets, the transport choices that actually exist taking account of accessibility differences and transport cost structures, and the differences in what are ostensibly similar modes of transport. Transfer of VTTS results from international modal choice studies are likely to be particularly difficult because of the differences in social perceptions of each mode, what competing modes exist, the lengths of trip being undertaken, and the speed, comfort and reliability offered by each mode.

Despite these difficulties, New Zealand practice will very likely continue to be influenced by international research findings. Therefore some effort should be put into the process for selecting and evaluating international research results, so that those which are not pertinent to New Zealand conditions are excluded, and those that are pertinent are interpreted accurately.

While monitoring international research findings in this way will be of advantage, it should not be done in place of New Zealand research efforts. Several empirical studies will be needed to build up sufficient confidence to differentiate New Zealand traveller preferences. However, even only one or two studies could give the confidence needed to ensure that the values being recommended for project evaluation are appropriate to New Zealand conditions.

3.5 Practical Application for Project Planning & Evaluation

Whatever structure of VTTS is eventually recommended for future use, the practical implications of applying the values must be taken into account. At present the PEM provides VTTS per hour for drivers, passengers and vehicles, and hence "builds up" costs for typical mixes of traffic by type of road and, for urban arterial roads only, by time period.

3.5.1 Issues Regarding Application of Time Values in Travel Demand Modelling and Project Evaluation (Appendix 12)

Three general issues have been identified, as follows.

1. The PEM provides resource values for VTTS. This is adequate for situations in which no change in travel demand occurs as a result of the project. However, in variable demand cases, both behavioural and resource costs are required to obtain a theoretically correct evaluation, as discussed in Appendix 12.

2. Although not strictly related to the value of travel time, another problem area is the evaluation of minor road developments where only one or a few activities are supported by the road. In such cases the consumer surplus methodology, and the use of travel time and other road user costs as the measure of benefit, become somewhat artificial and would be better replaced by a full consideration of the economic reliance of the activities served on the access road.

3. The interpretation of transportation planning model outputs is an issue for the purposes of cost benefit analysis. This can present some problems, particularly for networks subject to congestion. Provided that networks are free-flowing or subject only to minor congestion effects, then a fixed demand assumption appears to provide the safest way of making a comparative evaluation (and is a requirement for example in the UK COBA procedures).

   However, this is unrealistic on a congested network. In congested networks, the integrity of the economic evaluation is likely to be conditioned by the mathematical structure of the model. In particular it will be dependent on how the model reflects increases in, or relief of, congestion and how it deals with short and longer term interactions (such as trip redistribution, and influence of accessibility on land use). Conclusions on these points cannot be easily drawn and are not attempted here, but the subject should be considered for detailed investigation.

3.5.2 Future Trends in Travel Time Values (Appendix 13)

Indexing on the basis of wage rate (or GDP/capita as per UK practice) is an imperfect mechanism, and preferably should be substituted by a plan to monitor the various factors which will influence behavioural VTTS over time. These have been identified by MVA et al. (1987) to include changes to: working hours; level of unemployment; proportion of retired persons; female participation in the workforce. Working hours, employment, the proportion of retired persons and female participation rates are statistics which are routinely gathered by the NZ Department of Statistics.

Evidence of the variation in VTTS between full-time employed, part-time employed, and persons not formally employed, and also the differences by age and family grouping, form a basis for differentiating those aspects which could conceivably be incorporated into the evaluation process through surveys of the travelling public. This leaves working hours per year and the utility to the employee of payment for full-time work as factors which would be used to modify the non-work VTTS for full-time working adults.

The theoretical basis and practical implementation of an improved method for annual indexing of the non-work VTTS could form an individual item of research or be included with research into the treatment of taxation and establishing the marginal cost of labour for in-work time savings. Such research should also consider long-term forecasts of change in socio-economic characteristics of the population, and how these should be incorporated into project evaluation. The output of such research would allow the PEM to include sensitivity of project cost benefit analysis to future economic growth, in a similar way to the UK practice.

3.5.3 Requirements for Representative Travel Time Data (Appendix 15)

Should a matrix of time values or, more likely, a base value with modifying additive or multiplicative factors be recommended eventually, the practical process of applying such a system in the evaluation framework needs to be considered. The process requires that characteristics used to differentiate VTTS among travellers either should be capable of ready identification and measurement in the field, or that special surveys should be undertaken to provide "standard" data over the range of transport situations likely to be encountered in practice.

The range of data requirements comprise:

- Typical mix of travel purposes for drivers and passengers by age/sex/employment status of person, type of vehicle, time of day, and type and location of road or public transport mode.

- For work-related travel purposes, the mix of occupational categories in a form which can be related to Statistics Department data on employment and wages.

Information of this kind is available only through roadside observation and interview surveys. Ideally, it would be useful to obtain correlation between the less readily observable traveller characteristics and features which can be observed without the need to stop traffic (for example the number of vehicle occupants and sex/age mixtures).

3.5.4 Treatment of Speed Limits in Evaluating Travel Time Savings (Appendix 14)

The present PEM does not allow any travel time savings from vehicles travelling faster than the posted speed limit on any link (i.e. length of road between two intersections), although it does allow for operating and accident costs corresponding to the actual speeds. While this issue does not relate to the estimation of time savings as such, it is covered in this section of the report because of its significance in evaluating time benefits in project evaluations. The issue is mainly of significance on urban arterial roads, where the average traffic speed under acceptable levels of service is typically 60-65 km/h even on roads with a 50 km/h limit. In such situations, even though motorists may perceive a traffic "problem" if congestion means they can travel at only 50 km/h, the present rules mean that little or no time savings can be attributed to relief of the congestion.

The present practice of limiting "evaluation" travel speeds to the posted speed limit was supported by the former NRB and then by the Transit New Zealand Authority. There were two reasons for their policy. First to recognise benefits from travelling faster than the posted limit would be regarded as condoning infringements of the traffic regulations; and second the setting of a speed limit can be interpreted as the expression of a social value of limiting vehicle speed. However, if this social value can be equated with accident risk, then this value may be better expressed as an accident cost increase with speed. It certainly seems inconsistent that the PEM requires inclusion of additional costs for vehicle operations and accidents arising from speeds above the posted limit, but disallows any time savings above the limit.

This issue would be considerably reduced in significance if posted speed limits were more closely aligned with the prevailing traffic speeds, particularly on higher standard outer urban roads. This may be achieved through a review of speed limit policies, in particular to allow more flexibility in speed limits in urban areas.

Resolving this issue is important because of its effect on the practical application of travel time values. However, no specific research project is required, although a restatement of the position and the desirable resolution of it may be useful.

4. PROPOSED RESEARCH PROGRAMME

4.1 Basis Of Research Programme Development

The programme of research into issues related to VTTS in New Zealand will need to take into account:

- The degree of uncertainty which the present lack of information or knowledge has on road project planning and evaluation in practice.
- The likelihood of research gaps being filled by international research which can be transferred to the New Zealand context.
- The resources required for research projects in terms of expertise and cost, and the amount of research funding which can reasonably be expended on the topic.
- The likelihood of projects achieving their target objectives and the pay-off in terms of improved confidence in road planning and evaluation procedures.

When considered under these four criteria, those aspects of VTTS which are peculiar to New Zealand, and will therefore not be filled by any international research effort, should be given a primary priority. These aspects are principally related to the application of VTTS theory and empirical research findings, such as reliable information on those socio-economic characteristics of travellers which influence their time constraints, and their behaviour in transferring time savings to work or leisure activities. Better information on wages, employment-related costs and effective rates of taxation that are specific to New Zealand are also required.

Of secondary priority, if research resources allow, will be designing a programme of empirical studies that provides reference VTTS in commonly occurring evaluation contexts. These will focus on savings of time in urban and rural road transport in situations where no modal substitution is involved. Studies of modal choice may be considered, but the results will be more specific to the cases studied. Any research in these areas will need to take into account and build on recent work on this topic, particularly that in the Auckland Transport Models Project (ATMP). Studies of VTTS for public transport trips will be given lower priority.

4.2 Outcome Of Workshop

A workshop was held in October 1992 at Transit New Zealand. Workshop participants included representatives from the Auckland Regional Council, private consultants, Ministry of Transport, staff of Transit New Zealand Transportation and Economics Sections, and the project consultants (including Dr David Hensher from Sydney University).

The draft Interim Report for the project was presented to the workshop participants and discussions ensued on each of the topic items. Some of the participants were able to provide instances of research into travel time preferences from New Zealand studies, and these were subsequently followed up. A strong opinion of the workshop was that VTTS should differentiate between commuters and other non-work travel purposes.

At the end of the workshop, the discussion was directed towards research priorities, with potential projects and other issues to be addressed being ranked on a scale of priorities. The project consultants took note of the views expressed and these were taken into account in defining and prioritising candidate research projects, as now outlined.

4.3 Candidate Research Projects

The following eight research projects have been developed to the draft brief stage, and indicative budgets have been estimated. Establishing the priorities of the eight projects are described in Section 4.4.

4.3.1 Project No. 1: Treatment of Taxation, and Compatibility of VTTS and Value of Statistical Life (see also: S3.2.4, S3.2.5, App. 3, App. 4)

4.3.1.1 Objectives

The objectives of this project are:

- To estimate an appropriate value for the average rate of indirect taxation on goods and services traded against travel time savings.
- To determine whether the behavioural to resource value adjustment that applies to VTTS should also be applied to WTP valuation of statistical life.
- To review international and New Zealand relativities between behavioural non-work VTTS and behavioural values of statistical life (VOL); to consider whether the relativity currently existing in the values used in the Transit New Zealand PEM are appropriate; and to recommend changes in this relativity if appropriate.

4.3.1.2 Background and method

The present VTTS contained in the PEM assumes an average rate of indirect taxation of 15%. This is a nominal rate and investigation is needed to provide a methodology and better estimate of this rate. This rate may have already been determined for other purposes and the investigation should first canvass government agencies (Treasury, Commerce, etc.), universities and research institutions.

The rate of indirect taxation is applied as a correction to the behaviourally determined VTTS to approximate a resource value (on the basis that the aggregation of behavioural values effectively nets out transfer payments within the economy). The correction factor is $1/(1+t)$, where t is the rate of indirect taxation.

While this correction is implicit in the VTTS, the VOL is also determined from WTP studies, but is not corrected in the same way. The validity of this position needs to be resolved.

For an efficient distribution of funding, an appropriate relativity should be established between the value of time (VOT) and value of statistical life (VOL). This relativity can be expressed through the ratio of VOL:VTTS, which has the dimension of hours. The project should explore the relativities implicit in the VOL:VTTS ratio in other countries which have adopted WTP values based on a substantial research base (e.g. UK, Australia, USA, Netherlands, other European nations). It should consider what factors may influence the relative values and whether the relativity would be expected to be similar across different economies. The investigation should draw conclusions on whether the relativity adopted in current New Zealand practice is defensible or should be changed.

4.3.1.3 Indicative budget

$5,000- $8,000.

4.3.2 Project No. 2: Stated Preference Study of Car Users on Rural Highways

(see also: S3.2.3, S3.3.2, App. 2)

4.3.2.1 Objectives

The objectives of this project are:

- To determine, by means of stated preference (SP) surveys, behavioural VTTS for car drivers and passengers on rural highways.
- To determine behavioural values of: increased reliability of journey time; travel in congested versus free-flowing traffic; and travel on an unsealed versus sealed road.
- To investigate the effect on behavioural VTTS of: trip length; car passenger versus car driver; traveller type/trip purpose.

4.3.2.2 Background and method

This project aims to provide an empirical basis for the VTTS used in project evaluation for rural highway improvements. The survey should examine the preference for time savings against a realistic measure of financial cost, such as vehicle operating cost (VOC) (although issues relating to perceptions of VOC would need to be considered).

International research has indicated that reliability of journey time can be as important to travellers as a time saving, and the project should be designed to incorporate this factor. The study by Senna (1991) should be considered as a starting point for the project design. The project should also take into account traveller preferences for travelling in congested versus free-flowing traffic, and the disutility of travelling on an unsealed road compared with a sealed road at typical levels of roughness.

The survey context should aim to identify behavioural values according to the destination purpose type, differentiating between business and non-work purpose, and identifying the relationship between VTTS, value of reliability and the fixed or variable scheduling of the destination activity.

Some ambiguity has occurred in international studies as to whether the behavioural VTTS, inferred from car driver choice, take account of the preferences of passengers, in whole or in part. A means of investigating this aspect should also be included in the survey design.

It is anticipated that SP methods will need to be used for this project and that more than one experimental design may be needed to cover the range of effects.

4.3.2.3 Indicative budget

$30,000 - $40,000.

4.3.3 Project No. 3: VTTS for Business Travellers

(see also: S2.3.1, S3.3.3, App. 6)

4.3.3.1 Objectives

The objectives of this project are:

- To establish more appropriate VTTS for business travellers, relative to their employment costs.
- To obtain improved estimates of the gross (variable) costs of employment for the range of groups involved in business travel, stratified by the nature of their employment conditions.

4.3.3.2 Background and method

The present PEM procedures for valuation of savings in in-work travel time are based on the MPL approach, using information obtained generally from the late 1970s. The approach and assumptions now used, have a number of deficiencies including:

- Variable labour on-cost components may be significantly in error,
- Employee hours of work are not well defined,
- Flexibility of working hours involved in many employment contracts has not been allowed for,
- Time savings used for leisure rather than work, or for useful work that may take place during travel, have not been allowed for.

The project would involve two sub-projects, corresponding to the two objectives above. The first part would involve market research on the extent to which savings in business travel time will result in increased work production and/or reduced employer costs, and on the extent to which the savings will result in increased leisure time.

This research would need to address at least the following three aspects:

- The extent to which any travel time savings would be spent in working or in leisure.
- The extent to which productive work is undertaken during travel, in terms of the percentage of travel time spent working and the relative productive efficiency of this time.
- Whether it is reasonable to value any saved time used for working at the average cost of labour (including any variable overhead components), or at a lesser rate than this.

The extent of these different effects can be expected to differ by business sector/employee type, transport mode and time of day, partly because of self-selectivity effects among travellers. The project will need to draw distinctions between travellers by form of remuneration (salaried/wage earners, incentive payments, etc.), and flexibility of working hours (fixed hours and times, flexitime, nominal hours that vary with work demands). The research would require in-depth interviews with business travellers sampled across various business sectors/employee types.

The second part would involve three main aspects:

- Review of the present classification of groups involved in business travel for suitability for analysis purposes.
- Obtain data on gross wage costs and hours of work of business travellers in each group.
- Obtain information on appropriate labour on-costs for the travellers in each group.

The research would involve interviews with selected companies in a range of business sectors. It would also involve deriving gross wage cost data from a range of standard statistical sources (refer S2.3.1).

4.3.3.3 Indicative budget

$60,000- $100,000.

4.3.4 Project No. 4: Valuation of Commercial Vehicle Time Savings
(see also: S2.3.11, S3.3.4, App. 7)

4.3.4.1 Objectives

The objective of this project is to undertake appropriate market research to obtain improved estimates of the effects of travel time savings and improvements in travel time reliability on:

- commercial vehicle driver/staff utilisation,
- commercial vehicle utilisation and fleet requirements,
- freight inventory/stock-holding costs, in general and for perishable goods in particular.

4.3.4.2 Background and method

The present PEM procedures for valuing travel time savings relating to commercial vehicles assume that vehicle fleet sizes (for commercial vehicles, taxis and business cars) will vary pro rata to any travel time change, while there will be no changes in fleet sizes for buses. The procedures also make no allowance for savings in freight goods costs through time savings. These assumptions need to be reviewed.

To achieve the above objective the project will involve market research (interviews, questionnaires, etc.) with a sample of New Zealand commercial vehicle operators and users of freight services. The main emphasis is to be on truck operators/users, but a small sample of bus/coach operators should also be included. The effects of changes in travel time reliability (variability), as well as of changes in average travel times, should be investigated.

The outputs required are:

- Improved relationships between travel time savings and vehicle fleet savings for the different categories of commercial vehicles. (The project is not required to translate these fleet savings into financial terms, as that will be done separately.)
- Improved estimates for any savings in goods costs resulting from savings in commercial vehicle average travel times and/or reliability of travel times.

4.3.4.3 Indicative budget

$30,000 - $50,000.

4.3.5 Project No. 5: Representative Travel Data (see also: S3.5.3, App. 15)

4.3.5.1 Objectives

The objectives of this project are:

- To improve the classification system for representative traffic data given in Appendix A4 of the PEM.
- To provide representative traffic data for this revised classification system.

4.3.5.2 Background and method

The traffic data required for economic evaluation differ from those required for road system design, and include vehicle occupancy, traveller type and trip purpose. The present PEM (Appendix A4) provides typical traffic characteristics to be used in the absence of direct survey data from the site. These data typify traffic by road functional category, time of day, work/non-work trip purpose and vehicle occupancy. The data have been drawn from a synthesis of available surveys from around New Zealand. Concerns are however that they fail to address certain types of road, such as suburban commuter routes and roads with a high level of recreational traffic, and that many of the data are somewhat out-dated.

The project is to be carried out in two stages:

Stage 1:

- Review the functional classification of road types and time periods currently given in PEM Appendix A4. Any revised classification should aim to cover all combinations of road type and time period commonly occurring in economic evaluation. The revised classification should be compatible with the functional classification of roads used in traffic planning and design. The vehicle type classification presently in use is not expected to need amendment, but this should be discussed with Transit New Zealand.

- Carry out a review of the travel and traffic survey results from recently completed transport studies in Auckland, Wellington, Christchurch and Dunedin, and from any other recent sources of traffic data (held by Transit New Zealand, Ministry of Transport, local authorities and consultants).

- Design and prepare a budget estimate for traveller surveys to provide data on vehicle occupancy, on whether travel is being undertaken during paid working time, and on origin and destination activities. Surveys should cover drivers and passengers. While the surveys will require interviews of vehicle occupants, either directly or by reply-paid questionnaire, attention should be given to linking observable characteristics of moving vehicles with occupant trip purpose (such as by time of day and occupant mix). Sex, age, occupational status and nature of employment of occupants are to be recorded.

Stage 2:

- Stage 2 will be the implementation of the travel surveys designed in Stage 1, and the collation and analysis of the data therefrom. This data will be amalgamated with the information from Stage 1 to give completed updated tables for PEM Appendix A4.

4.3.5.3 Indicative budget

Stage 1 $15,000.

Stage 2 $60,000 - $120,000 (to be refined during Stage 1).

4.3.6 Project No. 6: Forecasting and Updating Unit Time Values
(see also: S3.5.2, App. 13)

4.3.6.1 Objectives

The objectives of this project are:

- Part A - To determine the most appropriate basis for forecasting changes in unit values of time over the longer term required for project evaluation purposes.
- Part B - To investigate the extent to which appropriate forecasts exists for the forecasting variable(s) selected in Part A.
- Part C - To develop principles and procedures for updating the base VTTS values in the short term (annually) and medium term.

4.3.6.2 Background and method

The present PEM assumes that the "base" unit values of time remain constant (in real terms) over future years of the evaluation period. This is contrary to the practice adopted in a number of other countries and needs to be reviewed.

PEM also currently contains no standard procedures for updating unit time values, either annually or on a medium-term basis. Such procedures would be desirable. The project would involve three parts, corresponding to the three objectives above.

Part (A) would review the appropriate principle for any longer term forecasts, examine potential forecasting variables, and make recommendations on the most appropriate variable(s). (For example, the UK DoT adopts GDP/head as the variable for both work and non-work time.)

Part (B) is to investigate and report on the extent to which appropriate medium/long-term national forecasts already exist for the selected variable(s). (Original research on this aspect is not expected to be carried out within the project.)

Part (C) involves the development of principles and procedures for updating the VTTS in future years. In the short term (annually), it may be appropriate to update the base values using a readily available standard index (e.g. average weekly earnings). However periodically (maybe every 5 years), a more fundamental review of the values would seem appropriate. (For business travellers this would tend to follow the procedures developed in Project No. 3.)

4.3.6.3 Indicative budget

$10,000.

4.3.7 Project No. 7: Stated Preference/Revealed Preference Study of Route Choice, Tauranga Harbour Bridge (see also: S3.3.2)

4.3.7.1 Objectives

The objectives of this project are:

- To determine, by means of back-to-back stated preference (SP) and revealed preference (RP) surveys, behavioural VTTS for car drivers and passengers through a route choice study for urban commuters (and possibly also other non-business travellers) between Mount Maunganui and Tauranga City centre.
- To determine, through the above surveys, behavioural values for increased reliability of journey time and for travelling in congested versus free-flowing traffic.

4.3.7.2 Background and method

The prime aim of this project is to carry out revealed and stated preference studies of work commuter travel between Mount Maunganui and Tauranga city centre, to provide empirical evidence on behavioural VTTS for car travel in typical New Zealand provincial centres. The consultant should also consider whether the project would warrant extension to non-commuter (non-business) travellers.

In this case, the toll bridge provides a choice for motorists: they can choose either a longer untolled route around Welcome Bay or pay a toll and obtain a substantial time saving. Perceptions of relative VOC between the two routes should be taken into account.

It is anticipated that the survey sample will be drawn from residential occupiers on Mount Maunganui who would be possible candidates for using either route. The respondents would be asked to declare recent trips made across or round the harbour and their perceptions regarding relative time and distance, to be compared against field surveys.

The same sample would be also asked to complete a SP questionnaire which would ask for route choice given changes in the bridge toll (e.g. doubling or removing the toll).

The survey would need to control for "expense account" charges of the toll and to identify whether the driver was responsible for vehicle running costs. Business and private vehicles would at least need to be separately identified. Other matters, such as convenience of the toll collection (weekly ticket versus cash, discounts) would need to be considered when designing the survey.

4.3.7.3 Indicative budget

$25,000 - $35,000.

4.3.8 Project No. 8: Modelling and Evaluation of Time Savings and User Benefits in Urban Transport Networks (see also S3.5.1, App. 12)

4.3.8.1 Objectives

The overall project objective is to develop improved methods for estimating user benefits (particularly time savings) from road system infrastructure and management measures in major urban areas.

4.3.8.2 Background and method

Travel time savings are usually the largest single component of user benefits resulting from improving the road system in major urban areas. However, the present traffic modelling and assessment methods generally adopted for major urban areas (both in New Zealand and internationally) are usually insufficiently realistic to enable good assessments to be made of user benefits, particularly in highly congested conditions. For instance, many studies (e.g. Wellington Urban Motorway Extension) adopt a fixed trip matrix, in which the future year traffic volumes may not be consistent with the future level of network capacity (particularly in the "Do Nothing" situation).

Even the more "sophisticated" urban transport models (e.g. WRC GATS) do not reflect some of the behavioural responses which are most likely in congested situations or under potential management/pricing policies. For instance GATS does not reflect trip generation/suppression or changes in time-of-travel, which would be likely in such situations.

This project would therefore aim to develop improved methods for user-benefit assessment in urban network situations. It would build on international developments and also on recent New Zealand work including:

- Transit New Zealand project on Speed/Flow and Operating Cost Relationships.
- Auckland Regional Council ATM Project - model development and survey findings.

The project is expected to involve three main areas of work, as follows.

Part (A): Review of international evidence on the responsiveness of road traveller behaviour to changes in time and costs of travel. This is to focus on the different types of potential response, in both the short and longer terms, e.g. trip generation/suppression, redistribution, mode split, changed time-of-travel.

Part (B): Review of international approaches to modelling travel behaviour and assessing travel benefits in congested urban network situations. This is to focus on what modelling/evaluation approaches are most appropriate to reflect the significant types of traveller behaviour found (in Part A).

Part (C): Review of traffic assignment and economic evaluation methods currently used for modelling urban transport networks in New Zealand, in terms of their suitability for evaluating travel conditions and user benefits; and the development of proposals for improving existing methods as appropriate.

4.3.8.3 Indicative budget

c. $50,000.

4.4 Establishment of Research Programme Priorities

The proposed research projects have been scored against the following five criteria, on a scale of 1 to 5, with a high score associated with a greater need or better prognosis for an affordable and successful research project.

- Degree of uncertainty of existing knowledge (low = 1, high = 5)
- Magnitude of effect in project evaluation (low = 1, high = 5)
- Likely degree of improvement in knowledge (low = 1, high = 5)
- Transferability of international research (good = 1, poor = 5)
- Probability of achieving target objectives (low probability = 1, high probability = 5).

Our assessment of the score of each of the eight candidate projects against the above five criteria is presented in Table 4.1.

A weighting may then be applied to each criteria according to its importance and the weighted sums obtained to give an overall score. Our suggested weightings, also on a scale of 1 to 5, and the resultant overall scores, are included in Table 4.1.

These overall scores of expected "effectiveness" then need to be compared with the project costs in order to establish "cost:effectiveness" ratios and derive a priority ranking. The major difficulty in this process is assessing what is a worthwhile (pass-mark) incremental cost:effectiveness ratio, i.e. how much additional research cost is warranted to achieve a higher effectiveness score. A rigorous assessment of this issue would involve much more detailed quantification of pay-offs than is feasible in this report. In its absence, a more intuitive approach is taken, through examining the relative costs and overall scores of each project, and taking account of the views expressed at the workshop.

To assist in this assessment, Figure 4.1 plots the overall scores and estimated research costs for each project. The most cost-effective projects are those in the top left-hand corner, the least cost-effective in the bottom right-hand corner. In general, the results show some tendency for the higher-cost projects to be more effective, the lower-cost projects less effective. The project ranking is not clear-cut.

Our best judgement based on this information is to rank projects into three priority categories, as follows:

- Category A: projects 1, 3, 7
- Category B: projects 2, 5, 8
- Category C: projects 4, 6

These suggested priorities are included in Table 4.1.

The reader may make his/her own assessment of priorities, by varying any/all of the:

- evaluation criteria,
- scores on each criteria,
- weightings for each criteria,
- trade-off between incremental effectiveness and cost.

On the priority assessment given in Table 4.1, the three priority categories would involve the following approximate research budgets:

- Category A: $117,000
- Category B: $190,000
- Category C: $ 50,000

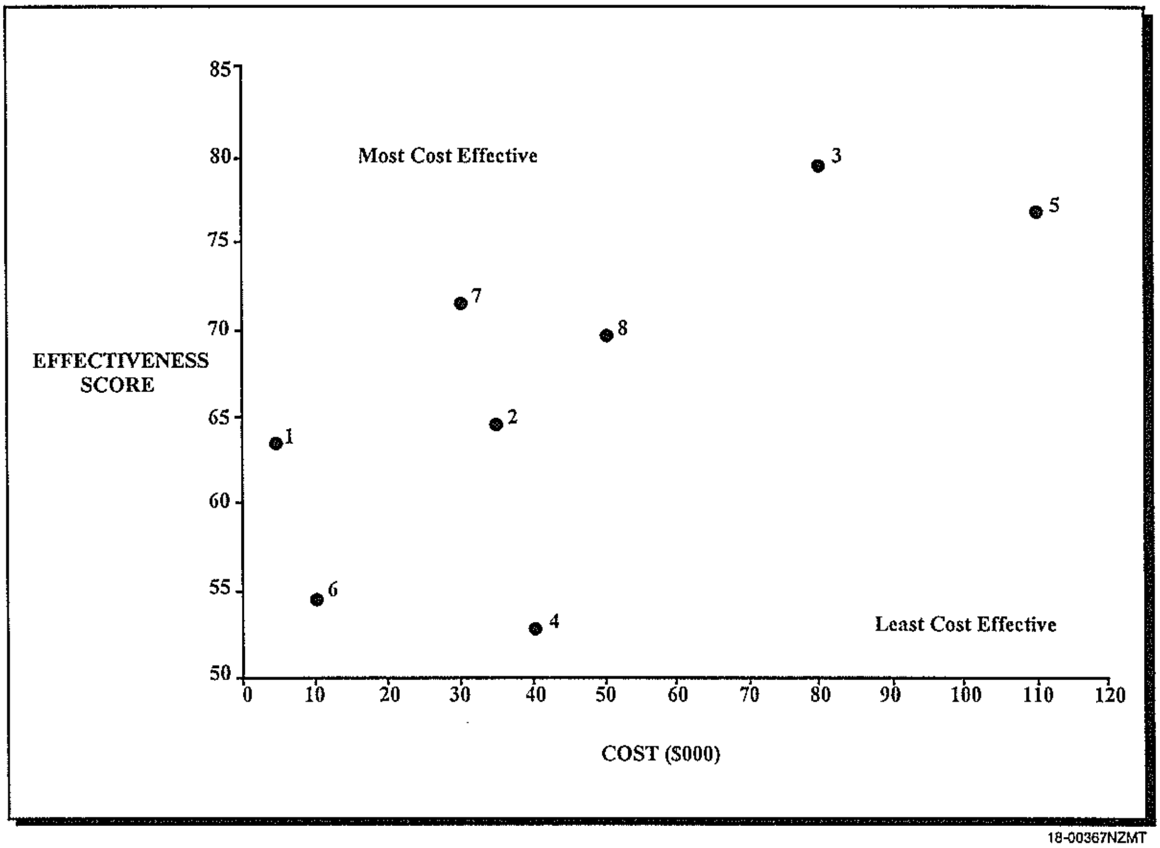
  Total $357,000

Table 4.1 Evaluation of priorities between candidate research projects [1]
(Score by Evaluation Criteria, Total Weighted Score, Estimated Cost, and Priority Category)

RESEARCH PROJECT	EVALUATION CRITERIA					TOTAL WEIGHTED SCORE	ESTIMATED COST[2] NZ$000	PRIORITY CATEGORY
	Existing Knowledge	**Significance in Project Evaluation**	**Likely Improvement through Research**	**Transfer of International Findings**	**Likelihood of Achievement**			
(Criteria weighting)	**(4)**	**(5)**	**(4)**	**(4)**	**(3)**			
1. Taxation treatment & VTTS:VOL compatibility	3	4	3	2	4	64	7	A
2. Rural car users SP study	3	4	3	3	3	65	35	B
3. Business travellers VTTS	5	4	4	3	4	80	80	A
4. VTTS for commercial vehicles	3	2	3	3	4	53	40	C
5. Representative travel data	4	5	4	2	4	77	105	B
6. Forecasting/ Updating unit values	4	2	3	2	3	55	10	C
7. RP/SP route choice study	3	4	4	3	4	72	30	A
8. Urban transport modelling & valuation	3	3	4	4	4	71	50	B

Note: (1) Refer text for further explanation
(2) Gives the middle of the range of estimated costs in Section 4.3

Figure 4.1 Effectiveness scores versus research costs for candidate reference projects [1]
(Note: 1 - 8 = Research Projects 1 to 8; see Table 4.1, Sections 4.4.1 - 4.4.8)



4.5 Other Issues for Further Consideration

This section summarises a number of issues identified in earlier sections which warrant further consideration in developing improved VTTS, but are not envisaged (at least at this stage) as separate research projects.

4.5.1 Equity Issues (Appendix 9)

Imposition of an equity VTTS is essentially a political matter. Although "even-handed" treatment of travellers has emotive attraction, the implications of ignoring variations in VTTS according to income, modal taste preferences or individual time constraints first need to be quantified before a well informed decision can be made.

4.5.2 Transferability of International Research (Appendix 11)

Possibly a case exists for a much more careful (and costly) analysis of selected empirical international studies to transfer the results into present day New Zealand dollar values, with appropriate adjustments for currency movements, taxation, and other factors. The output of such an exercise may be to establish appropriate values for New Zealand conditions with more confidence, in the absence of local empirical studies.

Our judgement on this issue is that such an analysis would most likely still result in a fairly wide range of plausible values, and that the gains therefrom would probably not be worth the effort. An analysis of this sort was proposed by Bates & Glaister (1990) in their review for the World Bank, and this should be followed before a decision is made.

4.5.3 Treatment of Speed Limits in Evaluation (Appendix 14)

The work undertaken has suggested that the present PEM practice should be modified to achieve more consistent treatment, in one of two ways:

- All user benefit components should be based on average speed on any link not exceeding the posted speed limit.
- All user benefit components should be based on the "unrestrained" speeds.

The work has also indicated that perhaps present speed limits should be reviewed selectively in situations where observed speeds substantially exceed the posted limit. Such a review process has been initiated by the MOT. If this does result in posted speed limits better reflecting the prevailing traffic speeds on individual links, then some of the worse inconsistencies resulting from the present practice would be removed.

4.5.4 VTTS Research in Main Urban Centres (Appendix 16)

The recent round of urban transport studies in the four main urban centres has provided limited information helpful in improving VTTS values. However the Auckland ATM project has undertaken model calibration based on RP data from recent surveys, and has also undertaken an SP research project on traveller behaviour (which covers mode choice, modal features, reliability aspects, etc.). It would now be appropriate to review the outputs from this work, to assess what further light they shed on urban traveller behaviour, including values of time by different modes and in different circumstances.

4.5.5 Public Transport Project Evaluation

As noted earlier, the present PEM is of very limited use for evaluating public transport investment projects, and such projects would be best covered in a separate Manual. No specific attention has therefore been given to deriving improved VTTS for public transport users in the research programme proposed. (The ATM project may provide improved VTTS for public transport travel.)

APPENDICES

A1. NON-LINEARITY IN VALUES OF TRAVEL TIME SAVINGS

A2. EFFECTS OF CONGESTION & UNPREDICTABILITY OF TRAVEL TIMES

A3. TAXATION TREATMENT

A4. COMPATIBILITY OF TRAVEL TIME & ACCIDENT VALUATION APPROACHES

A5. METHODOLOGIES FOR BEHAVIOURAL STUDIES

A6. VALUATION OF WORKING TIME

A7. VALUATION OF TRAVEL TIME SAVINGS RELATING TO COMMERCIAL VEHICLES

A8. EVIDENCE ON BEHAVIOURAL VALUES OF TRAVEL TIME SAVINGS

A9. EQUITY ISSUES

A10. VTTS FOR "SLOW" TRANSPORT MODES

A11. TRANSFERABILITY OF INTERNATIONAL RESEARCH

A12. ISSUES IN APPLICATION OF VALUES OF TRAVEL TIME SAVINGS IN TRAVEL DEMAND MODELLING & ECONOMIC EVALUATION

A13. FUTURE TRENDS IN TIME VALUES

A14. TREATMENT OF SPEED LIMITS IN EVALUATING TRAVEL TIME SAVINGS

A15. REQUIREMENTS FOR REPRESENTATIVE TRAVEL DATA

A16. EVIDENCE FROM URBAN TRANSPORT STUDIES IN NEW ZEALAND

A17. THEORETICAL BASIS OF THE VALUE OF TRAVEL TIME

A18. VALUE OF TRAVEL TIME SAVINGS FOR CHILDREN

REFERENCES

A1. NON-LINEARITY IN VALUES OF TRAVEL TIME SAVINGS

A1.1 Introduction

The question of linearity of VTTS for very small, moderate and large values of time savings, and depending on the context in which these savings occur, has long been a vexed question, and an area in which many attacks have been launched on the integrity of VTTS in project evaluation. This has historically formed a point of difference between practice in the USA and in other countries, with the incorporation of research findings of Thomas & Thompson (1970, 1971) in the AASHTO Red Book (AASHTO 1977). However, it now appears that the update of the AASHTO Red Book will remove this point of difference.

The conventional wisdom on linearity is that to treat time savings as non-linear would introduce inconsistencies and practical difficulties to project evaluation, as the combined effects of staged developments would no longer be additive. Project evaluation deals with systematic changes to the transport system in the medium term, assuming that people have a chance to adjust. This behaviour may well differ from short-term responses to small and possibly short-lived time savings, which may not be perceived by the traveller.

However, concern about this question still remains. For example, often doubts are expressed that small travel time savings can be used effectively in long-distance trucking operations. Another concern is that there may be a period of adjustment to a new transport facility, over which time savings gradually become more effectively employed. This whole question is bound up with habitual behaviour and thresholds required to initiate behavioural change. Such changes may be made as step functions rather than as a smooth continuous response.

The present PEM values adopt a linear assumption, i.e. a constant VTTS per hour for each vehicle type. This is the same approach as adopted in almost all other countries (but note the USA practice, recorded in paragraph 1 above).

This Appendix discusses the international evidence on the valuation of different sizes of travel time savings. The discussion covers the following main issues:

- perception of time savings
- project size and journey length
- short-term savings versus long-term savings
- value of large time savings
- empirical evidence to support the arguments
- implications for project evaluation.

The discussion encompasses considerations for both business and leisure time. In general the arguments of non-linearities apply equally to both applications of time. Where there is divergence, a discussion is given.

A1.2 Perception of Time Savings

One argument sometimes put forward is that small time savings may not be perceived by transport users, or perceived to be so small that they have little value, e.g. studies by Horowitz (1976) and Thomas & Thompson (1970, 1971), as quoted by Abelson (1986). Thus the perceived value of small time savings would be less than would be the case assuming a linear utility function. A related argument is that small time savings cannot be put to significant productive use, and therefore are of little value.

The UK SACTRA (Leitch Committee 1977) noted that some critics argue that it is wrong to assume that the savings of one second by 3,600 people is equivalent to one person saving an hour (refer MVA et al. 1987). However, SACTRA came to the view that VTTS was independent of the extent of the saving. It noted that a number of commuting value of time studies (involving small time savings) had estimated "typical" values for such savings. This view is supported by UK DoT (1987). DoT commented that the practice of having one unit value for all time savings implies only that the mean of the value distribution (i.e. the average value per unit of time) is the same for small and large time savings. It may be that some time savings are valueless while other savings are of greater than average value.

Bruzelius (1979) argues that if a consumer does not perceive a time saving, then the saving will have a value which is determined by the compensated marginal value of time as a resource (p.188). This means the time saved will accrue to the consumer and will have a value determined by the consumer's value of time at the margin. In the longer term, the time would be utilised as part of other activities so the (implicit) value would be a function of the use of time for that activity.

A1.3 Project Size and Journey Length

The amount of time saved on a journey will typically comprise an aggregate of small savings accumulated across a number of projects (e.g. the Leitch Committee (1977) report on trunk road assessment). BTE (1982, p.18) and Abelson (1986, p.62) argue that it would be inconsistent to value the overall time saving differently from its constituent parts. UK DoT (1987) states that:

> *... Development of the road network over time produces a series of small savings which when summed together have a large positive value. It would be inconsistent to forego an eventual large time saving by refusal to undertake schemes yielding the small time savings which are the elements of an eventual large time savings...*

In similar manner, Bruzelius (1979) argues that time savings associated with a single project should not be viewed in isolation. MVA et al. (1987, p.185) suggested that the benefits of the construction of the M25 motorway around London should be the same whether it was appraised as a single scheme or as a combination of a large number of small schemes. This view is supportable if time savings of different sizes all have (on average) a similar value. If smaller time savings are of lower value, then this view is not supportable as the benefits are likely to depend both on the length of the new route and on the proportion of the length used by different trips. The adoption of a non-linear assumption for VTTS would make the project evaluation dependent not only on the form of the investment and other investments in the network, but also on the pattern of journeys using the network. This would be a major difficulty for project evaluations.

A1.4 Short-term versus Long-term Savings

The literature on travel time savings is generally unclear on the time period that is being considered for the accrual of time savings. This would appear to be an important reason for divergence between researchers. Abelson (1986, p.62), for instance, notes that a trip-maker is likely to adapt his behaviour to expected regular savings in travel time even if once-off savings are not well utilised.

BTE (1982) suggests that small travel time savings are worth less than large time savings in the short run. It notes that savings in travel time are generally non-accumulative. Thus time saved in small units (unlike money) cannot be easily transferred from activity *i* to anything other than activity *i+1* (p.16). This is particularly so when, in many instances, constraints require certain activities (e.g. work and shopping) to take place in certain hours. BTE argues that larger time savings, by contrast, might enable re-scheduling of a sequence of activities and so allow time saved to be transferred to activities with high values. Thus the size of a time saving would determine, BTE argues, the extent to which an individual might use the saving for alternative uses (p.18), and thus influence the value which would be attached to that time saving.

Waters (1991) similarly argues that VTTS is a function of the block of time which is saved. Time is valued for what can be done with it so that, with a larger block of time, more options are available (p.63). He instances the case of small time savings for commercial truck drivers and suggests that small savings are less likely to be able to be used productively (p.20).

Miller's (1989) example that a traveller may place a high value on a small saving in travel time if the traveller is late (p.2) also relates only to the short-term situation.

Waters notes that indivisibilities do exist in the usage of time, however, that might well apply across both short-term and long-term approaches. Many people would place a very low value on a small time saving but, for a few people, that small amount of time could be pooled with other amounts of time and be much more valuable. It follows, suggests Waters, that for many projects the size of time savings will be highly skewed, in that most people will experience a very small time saving whereas a few may save a large amount of time. As such, if the values of time do differ by size of time saving, use of a mean value of time would lead to an overstatement of the value of time saving (p.66).

MVA et al. (1987) recognise that indivisibilities may exist in the units of time which are useful and that time savings may accrue in magnitudes smaller than this minimum. As such there may be "slack time". MVA argues, however, that additions to the slack time will in some cases take the aggregate slack time above the threshold and thus enable productive use of the time. MVA argues that, in general, slack time in aggregate will be greater than the sum of the small increments accruing and hence that, on average, it would produce *"... useful time savings equal to the sum of all actual time savings.."* (p.185).

MVA nevertheless acknowledges that, in the short-term, such an assumption may not hold: ...

> *"Our own exploratory surveys and some evidence from other researchers lend support to the idea that small time savings should have a lower unit value, when considering individuals in the short term ..."* (p.185).

Travers Morgan (1977) noted in their business survey that a small, but significant, proportion of its sample of employers and employees indicated doubt about the total aggregation of values of very small time savings. It was noted, however, that these survey responses were inevitably made in the short term and could not take into account the long-term adaptation (p.105).

A1.5 Value of Large Time Savings

Generally, the literature concentrates on non-linearity issues with small time savings rather than with large time savings. Nonetheless, the same arguments would appear to apply in relation to large time savings. The view of the MVA et al. (1987) research was generally that the value of time savings appears to reduce with increasing trip length. MVA et al. also note though that

> *"... on the one hand our theory would lead us to expect very large time savings to have smaller unit values than small savings due to the effect of diminishing marginal utility ..."* (p.68).

This interpretation treats time as a product in itself rather than as a "budget constraint". If treated as a budget constraint akin to money, the appropriate question might be whether diminishing marginal utility would set in for the range of activities pursued with the time saved. However it seems unlikely that this would be the case.

Miller (1989) quotes Lee & Dalvi (1969) as having found that VTTS consistently decreased as travel time increased (p.11). This might be expected because alternative modes might be available and would be increasingly attractive as travel time increased. Horowitz (1976), by contrast, found that if the length of trip was held constant, the value per minute saved increased for most trip purposes (Miller 1989, p.11). Miller argues that studies of travel time value need to be controlled for trip length. If so, then the value per minute saved will be constant, as found by Horowitz (1978, 1981).

A1.6 Empirical Evidence

Little evidence supports either view on the non-linearity of the value of travel time. In any appraisal of empirical results, it is imperative that the situation is defined clearly and is segmented into saving attributes, e.g. short term versus long term, short distance versus long distance, and small project versus large project. It would appear that differences between researchers arise because of the failure to account for these different characteristics. Waters (1991) notes, for instance, that VTTS may be a function of the *relative* amount of time saved (p.66).

Waters quotes AASHTO (1977) as having adopted the results obtained by Thomas & Thompson (1970, 1971). This study concluded that the relationship between the value of time and the amount of time saved was an S-shaped curve. Little (or zero) value would be made for small time savings of less than 5 minutes, increasing rates as saving increases to about 15 minutes, and increasing at decreasing rates beyond 15 minutes (p.64). Critics indicated, however, that the data were not revealing about times of less than 5 minutes and that the influence of different lengths of journey were not taken into account (p.64).

Waters also quotes Blomquist & Miller's (1990) study of seat belt use had concluded that savings of 4 seconds were worth 63% of the wage rate (p.64).

MVA et al. (1987) undertook a revealed preference study of alternative crossings of the River Tyne in England. They concluded from the study that the unit values of time reduces as the time saved as a proportion of the total journey time reduces (p.158). This may be linked with the disutility of travel which, MVA suggest (on the basis of other research undertaken in North Kent) increases faster than linearly as travel time increases (p.158).

A1.7 Implications for Project Evaluation

If the value of time was accepted as being non-linear, this would imply that project evaluations would need to stratify the benefits of a project by the level of time savings that each user would accrue. Attention would need to be paid, nonetheless, to ensure that the benefits of an individual assessment would bear some relationship to the benefits of inter-dependent schemes in aggregate. For instance, if low aggregate time savings were attached to single projects, it might be argued that a group of inter-related projects would have the same aggregate VTTS.

Both Waters (p.66) and MVA et al. (p.65), for instance, accept that there may be cases (at least in the short-term, says MVA) where a small time saving is worth less than large time savings, but that it would be very difficult to assemble and analyse such projects. Waters acknowledges that, there would need to be

> ... *"an extraordinary amount of detail to record various small increments of time saving and value them differently depending on what other small road improvements were accompanying them ..."* (p.66).

Miller (p.8) indicates that to vary the value of time as the amount of travel time saved varied would be ... *"an iterative nightmare..."*, involving convergence of estimates of individual project benefits with aggregate project benefits. The splitting of time valuations into urban and inter-urban schemes represents one practical form of introducing non-linearity, recognising the basis for non-linearity in the relative disutilities of the journeys.

Bruzelius (1979, p.189) and Waters (1991, p.67) suggest that alternative approaches might be to conduct sensitivity analysis of the results of an appraisal. Waters suggests, for instance, that the distribution of time savings by size should be recorded as a useful sensitivity analysis of projects (p.67). Bruzelius proposes that all projects be evaluated with the same time value and then, as a second step, sensitivity tests could be carried out to determine whether the viability and ranking of projects were sensitive to adjustments in the value of time (p.189).

Overall, neither the theoretical nor the empirical evidence for non-linearities in the valuation of travel time savings are very strong. In this situation, there are strong practical advantages for project evaluation in adopting the linear assumption.

A1.8 Concluding Comments

In interpreting the differing opinions on travel time savings, differences arise because different parameters are used. For instance, for road investment it is clear that a long-term view is needed. Consequently, research which points out that small time savings cannot be exploited is usually taking a short-term view. In the longer term it is assumed that activities can be re-scheduled to exploit the time saved. Where activities are indivisible however, it seems plausible that some people will be able to fully exploit the time saved while others will not. On balance, however, it seems reasonable that in the longer term opportunities will exist to exploit the time saved. If time saving is considered not as reducing the opportunity cost but as a function of the rising discomfort of the journey, then a higher value may be appropriate for larger time savings, if the discomfort is assumed to rise more than proportionately with time. These values will vary with the mode of transport and the opportunities for using alternative modes.

The other key point raised is that the time saved may not be in isolation to other time-saving road projects and that it is the level of aggregation, or otherwise, of these projects which will affect the outcome of a project evaluation. Thus, if a lower value is placed on small time savings, a project assessed in isolation would accrue a lower level of time saving benefits than if it were part of a larger project where additional time was saved.

In reality, the problem is not that the project is considered in isolation but that the value of time is not correctly established. This value will depend on the use of the road system and thus how much, in aggregate, a traveller will save. There may be as much bias, for instance, that an aggregate project will *over*-estimate time savings for an individual if it incorrectly assumes the individual will be using all of the road link. Therefore, the difficulty in ascertaining the appropriate values of time for different users has led researchers to accept one single (constant) value of time for a given trip purpose, though accepting the need for carrying out sensitivity analysis on the results.

Intuitively, in the longer-term, the value of time savings would be expected to be linear. The opportunity cost of a minute of time could be the same as for a minute of time which is saved together with four other minutes. The mode of travel may influence the value of time, however, if comfort of the journey varies. For example, the threshold of discomfort may influence time valuations to the extent that, in the extreme, a modal switch might occur or the journey is not made. The MVA et al. results from North Kent are notable in showing that disutility of travel increased faster than linearly as travel time increased. Thus, it is not the utility value which is attached to time, per se, which could cause variation in the longer term, but rather the disutility value of the uncomfortable journey.

If VTTS is a function of both the opportunity cost of time and the value that individuals would place on reducing discomfort, then, given discomfort thresholds, there may be a non-linearity in travel time savings. Ultimately, however, a person may choose not to travel or to travel using an alternative mode.

The impracticalities of segregating small time savings from large time savings may, however, lead to the decision to not vary the VTTS except across environments, e.g. urban versus rural, where the level of and type of discomfort will vary.

In summary, there are no compelling theoretical or empirical reasons to adopt non-linear assumptions on values of time savings, and there are strong practical reasons in favour of adopting a constant unit VTTS. It is practical to vary the value of time savings across environments, e.g. urban versus rural. Travel time savings are valued because of the freeing up of time for other activities (either work or leisure) or because of the reduction in disutility from the discomfort of travelling. In the longer term, even small increments of time can be exploited and, even if not perceived, will be implicitly valued. The value of time is therefore constant (though accepting that workers' overtime rates will be an institutional exception).

The value of units of time savings for leisure purposes will, however, vary because variations in journey length or environment (e.g. congested urban roads) will generate different levels of disutility from discomfort. For this reason there are non-linearities in the value of leisure travel time savings. In practice the application of a broad range of valuations across individuals (depending, for instance, upon their journey length) is impractical and it is for this reason that linear valuations are used.

This does not preclude, however, variation in valuation across environments. As the assumptions on valuations will be necessarily broad, the sensitivity of a project's viability or ranking should be an essential test of the vulnerability of the decision-making choice to the assumptions made.

A1.9 Recommendations

Based on the above appraisal, recommendations are that:

- Constant "base" unit values of travel time (for a particular user group, journey purpose, etc.) continue to be adopted in the PEM, as in equivalent manuals in almost all other countries.
- Further research or investigation on this topic would not be worthwhile.
- The effects on changes in VTTS of changes in comfort factors and in the reliability/predictability of travel times should be further explored.

A2. EFFECTS OF CONGESTION & UNPREDICTABILITY OF TRAVEL TIMES

A2.1 The Present PEM Approach and Rationale

No explicit recognition of congestion and uncertainty in travel time as factors influencing the VTTS is made in the PEM. In the Working Paper on VTTS (Beca 1992), congestion and reliability are raised as issues (p.18). It is proposed there that basic values for free-flowing traffic and predictable arrival times should be factored by up to 1.4 to allow for congestion and reliability effects. However these recommendations have not yet been put into practice in the PEM.

A2.2 Rationale for Recognising Congestion and Reliability Effects

Transport improvements which lead to reduced congestion and to more predictable departure, travel and arrival times can potentially produce benefits over and above the opportunity value of the time transferred to other uses. There are two separate effects:

- Travelling conditions are less unpleasant when traffic is free flowing. Psychological stresses occur in heavy traffic arising from frustration at not being able to control the speed of travel, the small separation from other vehicles, and the extra concentration required in driving. When stopped, time is perceived to pass more slowly than when in motion and therefore has a greater perceived disutility.

- If departure, travel and/or arrival times are uncertain, then additional time may be budgeted for the trip, i.e. a "safety margin", particularly if the subsequent activity has a firm perceived deadline, such as meeting an appointment or making another transport connection. The uncertainty also engenders a degree of anxiety that the extra time allowed may be insufficient.

The two effects tend to be linked as congested traffic conditions lead to unreliability in arrival times.

For public transport journeys, uncertainty can manifest itself in both the time of service departure and the time of arrival, leading to "slack time" at the public transport stop and at the destination. On the other hand, uncertainty for a private transport journey is normally confined only to the travel time, which may result in slack time at the destination. Some overlap occurs between the value of waiting time and the way in which reliability is treated in empirical studies. Depending how waiting time is estimated or measured, part of the "safety margin" may be included.

A2.3 Evidence from International Studies

A2.3.1 Brazil (Senna 1991)

Senna (1991) suggests a framework for valuing variability in travel time. He introduces to the debate the individual's attitude toward risk, a concept which is well known in risk analysis. People (and organisations) may be risk-takers or risk-averse and all shades in between. In risk analysis the mean of the value of all possible outcomes weighted by their probability is the expected value, denoted *E*. For variations in travel time, there will be an expected value E_t. The traveller will associate a utility with each possible travel time and there will be an expected value of this utility, E_u. If the utility of the expected travel time $U(E_t)$ exceeds the expected value of the utility E_u, then the individual is a risk-taker. If it is less, then the individual is risk-averse.

Senna carried out a stated preference (SP) experiment using paired choices between trips of varying regularity of travel time, the more regular trip time being associated with a higher cost. The results of the study gave mean values of time saving (which incidentally reduced with increasing trip length) and indicated that, on the whole, travellers in this situation (Porto Allegre, Brazil) were risk-takers, rather than risk-averse. The disutility of travel time variability was found to be considerably higher than the utility of absolute travel time saving, i.e. in all cases it was of more value to the traveller to reduce uncertainty in journey time than to reduce the average journey time. For minor uncertainty in travel time (low variability), the unit disutility was less than for high variability.

The results are indicated in Table A2.1 and given relative to the VTTS for journeys of 15 minutes, shown as 1.00 (the reference gives monetary values in Brazilian Cruzieros, which are difficult to relate to New Zealand currency and wage rates).

Table A2.1 Results of SP experiment to determine value of journey time variability (Senna 1991).

Travel Time (minutes)	VTTS (index)	Value of Journey Time Variability (index)		
		Low	**Medium**	**High**
15	1.00	1.61	2.44	3.28
20	0.92	1.93	2.97	3.93
30	0.81	2.19	3.35	4.44
45	0.72	2.38	3.60	4.83
60	0.66	2.57	3.93	5.22

A2.3.2 UK Motorway Users (Black & Towriss 1990)

Black & Towriss (1990) provide a review of the theoretical framework and empirical studies and describe their own empirical study of car travellers using a motorway. The survey was by post-back questionnaire handed out at petrol service stations in the UK. Mean length and time characteristics of the journeys intercepted were 250 km and 203 minutes respectively. About 60% of travellers said they had to arrive at a particular time. Slack time was generally allowed between planned arrival and the appointment time, with 72% planning to arrive up to 30 minutes before the appointment.

Travellers were asked to allocate 10 points to categories of expected earliness or lateness (in order to provide a probability distribution) and the mean of these was used to infer the chance of being later than planned (35%) and late for the appointment (virtually nil). Travellers were invited: (i) to bid for a lower level of uncertainty in arrival time for the journey just made; (ii) to identify the maximum extra journey time that they would be prepared to undertake within the same overall time frame given the lower uncertainty; and (iii) to identify the maximum delay in starting time within the same overall time frame that they would be prepared to accept given the reduced uncertainty.

The results indicated that those with a specific appointment were prepared to pay £2.82 for a reduction in the standard deviation of travel time from 25 minutes to 12 minutes; and that the reduction in uncertainty corresponded to 20 minutes longer journey time or 20 minutes later departure time. (Incidentally, the VTTS found in the study was 12.05 p(pence)/min, somewhat lower than expected from the DoT appraisal values.)

Given that current appraisal values do not take account of uncertainty, the conclusion was that, in this case of motorway travellers, the VTTS could be under-estimated by 15%.

A2.3.3 UK Commuter Travel (Pells 1987)

Pells (1987) conducted a SP study of commuter work trips of university employees in Leeds. Pair-wise choices were presented to the participants, who were asked to categorise their choice into definite, probable, or indifferent to one or the other option, these choices being translated into numeric probabilities. The choices given were between one option which guaranteed regular but early arrival at a destination compared with another which also provided regular arrival but with later arrival, and less slack time at the destination. The experiment was oriented towards morning commuting journeys to work, with the hypothesis that extra time at home would be preferred to slack time at the destination. Separate experiments were conducted for early and late arrivals. However for late arrivals, the choice was between different frequencies of lateness, once per fortnight and once per month

The analysis provided values for reducing slack time before work of between 1.4 and 1.7 p/min, and the value for avoiding lateness between 6.5 and 7.9 p/min, depending on frequency. The study also revealed some differences between values of reducing slack time by sex of traveller, by long versus short journeys, by occupation category, and by income. The differences by sex could be attributable to greater time constraints for women on time at home before work. Those living further away also appear to accept greater absolute values of delay compared to those working close to home who expect more reliability in journey time.

A2.3.4 UK Car Travel (MVA et al. 1987)

MVA et al. (1987) did not include a full treatment of reliability and congestion in their research design. However, they did explore differences in VTTS between travel within and outside built-up areas in a study of long distance car travel. The results led them to suggest that VTTS could increase by up to 40% in the presence of congestion, or by even more in extreme conditions.

A2.4 Conclusions

Reliability in journey time and arrival time have been identified as important choice factors for both public and private transport. Recent studies indicate that reducing the uncertainty of arrival time may quite commonly be of equal or even greater value to travellers than reducing the average travel time on a particular journey.

The disutility of travelling in congested traffic conditions is a separate effect, but is likely to be positively correlated with the disutility of uncertain arrival time. The magnitude of this effect is not as well determined.

The lack of guidelines on how to value improvements in reliability of transport service is an important omission in the current PEM. Probably sufficient evidence exists to suggest values for inclusion in the PEM which would at least acknowledge congestion and reliability effects. Suggestions have already been made to Transit New Zealand (Beca 1992) but these address the problem through a measure of congestion (stopped versus moving time, or level of service). Miller (1989) also recommended that congestion costs should be acknowledged by a 50% increment on driver VTTS for congested versus free-flowing traffic.

However, as reliability of arrival may be of more importance than congestion per se, guidelines would be better formulated if a measure of reliability was used rather than the proxy of congestion. But this may be difficult to achieve in practice.

A2.5 Recommendations

In any empirical studies carried out in New Zealand attention should be given to quantifying the disutility of uncertainty in journey time, arrival time, and traffic congestion.

A3. TAXATION TREATMENT

A3.1 The Present PEM Approach and Rationale

The PEM (p.2.3) notes that all costs given in the manual are net of taxes, duties and subsidies and that this is a requirement for social cost benefit analysis in the national context. Standard values for vehicle operating costs are provided net of taxes and duties, while for values for costs of road construction and maintenance, the market price net of GST is taken to be a close approximation to resource cost. For the value of time, PEM gives no further explanation of taxation treatment.

Beca (1992) discuss the treatment of taxation in overseas practice (p.5.9) and later in their report use a nominal value of 15% overall rate of indirect taxation on goods and services to modify a behavioural VTTS for non-work time to a value for use in economic cost benefit analysis. The method is the same as that used by the UK DoT, namely:

Economic VTTS = Behavioural VTTS/(1 + r),

where *r* is the rate of indirect taxation on goods and services.

A3.2 Accepted Treatment

The treatment of taxation for non-working time, which is based upon the willingness to trade time against money, 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 the non-working time savings should be valued at the behavioural rate divided by *(1 + r)*, as above. This is the approach which has been followed in the UK since 1977. Before then a further adjustment term was included to allow for taxation on the benefits accruing from the project when applied to other sectors.

This taxation adjustment has normally been applied to an equity value of time savings (as in the UK), although this is not an approach which should necessarily be recommended. Where the rate of indirect taxation differs widely between alternative time-transfer activities, then the application of an average rate can be grossly misleading. A study of the distribution of actual rates of taxation would be required to establish if the use of an average rate is really a significant problem in practice.

For in-work travel time savings, the value of output to an employer is its return net of any direct tax, and the cost of labour to the employer is its price before the deduction of income tax. If the resource cost of labour is its price in employment before the removal of income tax, then it is traditionally valued before indirect taxation is added. When work-related travel time occurs during a period commonly thought of as leisure time, a weighted average of the appropriate work and non-work values should be used, according to the proportions of time in and out of normal working hours. In the past (including New Zealand practice), all such time has been assumed to occur during normal working hours. Defining "working hours" in respect of alternative time use is quite difficult for some groups in the community. Further discussion of issues relating to the valuation of travel in working time is given in Appendix 6 of this report.

A3.3 Model Suggested by Forsyth (1980)

The treatment of taxation in VTTS has been questioned by Forsyth (1980). In reviewing economic theory for the shadow pricing of costs in general he states:

> *...The general conclusion of these studies is that for deriving a shadow price of a resource for example for cost-benefit purposes, it is incorrect to use either a "resource" (or individual) valuation or a market (or productivity) valuation alone. It is necessary to combine the two, with tax rates and supply and demand elasticities entering as parameters into the shadow price equation. The same reasoning should be applied to travel time, whether in work or leisure hours. In addition, the existence of taxes other than those which directly influence the work/leisure choice will have a bearing on the evaluation shadow price of time..*

Forsyth bases his analysis on the specification of a utility model confined to a single individual. In this closed system the individual produces his consumption requirements, while income tax and other taxes are fully reimbursed by government in the form of various direct or indirect benefits. No minimum or maximum time constraints are imposed on hours of work. Forsyth justifies this by the argument that, for large groups of individuals, there is sufficient flexibility for an effective choice of working hours. This point is probably debatable. Travel itself is not attributed with any utility or disutility although Forsyth's view is that the analysis can be readily extended to allow for this. He also introduces the concept that increases in travel speed provide a wider choice of activities, so that some distinction is drawn between travel time savings arising from distance shortening as opposed to increased journey speed.

Two ways in which travel during work time may translate into other uses are suggested. First, if the work task requires some fixed minimum travel for its completion, then time savings may go in part towards increasing the time spent working, thus increasing total production. Second, if travel is an integral part of the production process, then a reduction in travel time will allow more such journeys to be undertaken and will alter the productivity of labour.

In the Forsyth model, as in most of the utility model specifications of time duration of consumption, the individual's valuations are responsive to after-tax earnings. However in Forsyth's model, the individual's valuation (and by extension total social benefit) is greater by the amount of benefit returned through government spending, which is equal to the marginal additional direct taxation from the extra production achieved through the time saving.

This model leads to conclusions that, depending on the time transfers which take place, behaviourally derived values of non-work travel time may need substantial upward adjustment to give an appropriate resource value. For work travel, however, the adjustment may need to be either up or down. For situations in which increased travel speed provides more accessibility to non-work activities and the time is merely transferred into longer distance journeys, behaviourally derived values may need to be corrected downwards to give an appropriate resource value.

Forsyth applies his findings to Australia, UK and the USA, using parameter estimates for wage rate, marginal direct and indirect tax rates, and behavioural values for non-work time taken from various studies.

The issues raised in Forsyth's paper were followed up with him as part of this study. It appears that the main issue is whether time savings are re-allocated to working or non-working time, rather than whether or not the travel itself takes place during paid working time.

A3.4 Conclusions and Recommendations

The generally accepted treatment of taxation used to infer a resource value of non-work time saving from a behavioural value is to divide the former by (1 + the indirect rate of taxation (r)).

Should New Zealand embark on empirical studies for VTTS, then a mean value of the indirect tax on the substituting activities needs to be properly established. If the variations in these indirect tax rates is substantial, then different shadow pricing factors would need to be developed for different time substitution effects.

The analysis by Forsyth (1980) raises questions about the treatment of taxation which have been considered. It appears that the main issue is that of identifying time re-allocation to work or leisure activities. If this can be identified, then the MPL approach can be used for that component of time saved which goes into productive work, and the WTP approach can be used for the non-working component.

A4. COMPATIBILITY OF TRAVEL TIME & ACCIDENT VALUATION APPROACHES

A4.1 Introduction

In 1991, the PEM simultaneously introduced new unit VTTS and values for road accident savings. The accident cost values were very substantially increased, with most of the increase attributable to the adoption of a Willingness-To-Pay (WTP) value for preventing a statistical death, commonly referred to as a Value Of Life (VOL). The relativity between VOL and Value Of Time (VOT) in project evaluation was substantially altered, with much greater emphasis being given to accident prevention in comparison to saving time or Vehicle Operating Costs (VOC) than had historically been the case.

Some empirical studies have examined the choice of travel speed as a context within which to explore trade-offs between time saving, risk of injury through accidents, and money through perceived vehicle operating cost. Miller (1989) comments:

> ... *Safety-oriented choices also can yield values of time, although potentially flawed ones because of the heroic calculations required to separate off the value of safety and the discomfort and inconvenience of safety equipment. ...*

This also draws attention to the relativity between VOL and VOT, and raises the question of whether there should be some linkage of the two values.

When the UK DoT introduced revised values for travel time savings (UK DoT 1987), it chose also to raise the evaluation values for injuries to maintain the same relativity as before, noting:

> *... the choice of a value is essentially a political assessment of the balance to be struck between mobility and safety . . . The new values have been set so as to ensure that, for the present, the existing overall balance between the benefits of road investment from journey time savings and from accident savings is maintained. ...*

During the process of establishing a revised value of life for inclusion in the PEM, it was suggested that, because the WTP VOL studies involved an interpretation of personal preferences in trading marketed goods against risk of injury or death in a similar way that WTP studies interpret travel time savings, then it should also follow that any adjustment for taxation effects applying to behavioural values of time should equally apply to the value of life. However this argument was rejected at the time by the NZ Ministry of Transport (MOT).

A4.2 Relativities between Value of Time and Value of Life

The VOL and VTTS can be compared in equivalent years. Before 1991, the National Roads Board Economic Appraisal Manual (TR9, Bone 1986) recommended values with implied relativity of 7.6 years of leisure time per value of statistical life. In 1991, the change to a WTP value of life raised this to 37.4. By comparison, the UK maintained a relativity of 18.8 years.

Guria & Miller (1991) carried out a SP speed choice survey in which drivers were asked how fast they went on a familiar road in good weather conditions and then in a storm. The calculated time difference was compared to the increased risk of fatal injury, indicating a WTP value of 253,000 hours of travel time (28.9 years). This was suggested to be compatible with Miller's

(1989) recommended value of car driver leisure travel time saving of 60% of the wage rate and 40% for car passengers (54.5% for occupants overall, equating to $1.845 million VOL).

Guria & Miller went on to infer survey respondents' rate of discount (4.8 to 6.4%) and WTP value per hour of life (120% of the wage rate). Overall their contention is that individuals' speed choice behaviour, WTP VTTS, WTP VOL, and discount rate for future consumption are in harmonious balance. They comment

> ... *The speed choice questions make it clear that the values of life and travel time are related. Good policy analysis demands keeping them in tune. ...*

A 25% value of travel time should be used with a value of life of $0.85 million, a 60% value with $2.00 million. On this basis the current value of time for a car driver at 46% of the wage rate (before indirect tax adjustment) equates with $1.5 million value of life (pre-tax adjustment).

There is evident merit in the contention that WTP values of time and life should be related. Whether the relativities suggested by Guria & Miller are sufficiently well founded can perhaps be argued. Miller's (1989) recommended value of driver time is based on detecting a "central tendency" in a review of a range of VTTS studies, and other reviewers may come to a different conclusion. For example Waters (1991), undertaking a similar exercise for Canada, notes that the selection of VTTS studies available to the reviewer can influence the conclusion. He cites the choice of an appropriate VTTS for car commuting, as follows: Chui & McFarland (1987) arrived at a value of 80%; Miller (1989) at 60%: Waters himself 50%; and the UK DoT (1987) 40%.

In the speed choice study, the assumption is that drivers' behaviour is conditioned by objectively measured risk, but in practice a conscious choice will not be made between time saving and risk of injury, and it seems intuitively likely that risk will be misperceived. A further concern is that speed is being interpreted as a time saving behaviour when, in part at least, it is being preferred in its own right as a sensation. This makes the inference of VTTS from VOL or vice-versa through a speed choice study somewhat doubtful.

A4.3 Conclusions and Recommendations

It is reasonable to expect that WTP values for time saving and saving of statistical life should be linked. Plausible values appear to lie in the range of 30% to 90% of the wage rate for non-work value of time, and $1 to $4 million ($NZ 1991) for VOL. A higher VTTS should indicate a higher VOL, but whether the relationship between the two can be reliably inferred from available evidence is open to debate.

Having settled on appropriate values of time and of statistical life, Transfund New Zealand would be advised not to alter one without giving serious consideration to the need to alter the other.

The recommendation is that further work be undertaken to:

- Review whether the conversion from behavioural to resource cost values is made consistently in VTTS and VOL, and
- Further examine the relative values adopted for non-work VTTS and for VOL (refer Section 4.3.1 of this report for further details).

A5. METHODOLOGIES FOR BEHAVIOURAL STUDIES

A5.1 Introduction

No empirical studies with the principal purpose of identifying travel time and cost trade-offs had been carried out before 1993 in New Zealand.

Weaknesses or areas of uncertainty in empirical studies undertaken internationally should therefore be addressed, discovering which methodologies have proved most successful internationally, identifying any weaknesses in those studies, and then considering how the best of international study methodologies can be applied in New Zealand and the practicalities and costs of so doing.

A5.2 Revealed Preference (RP) Versus Stated Preference (SP) Methodology

From studies over the last 10 years or so, SP methodologies have moved from being regarded as rather suspect to being the preferred method for experimental studies of traveller preference. This advancement has been achieved by carrying out convincing back to-back RP and SP studies which have provided confidence that well designed SP experiments can elicit realistic measures of traveller preference. With this confidence established, the increased control possible in a SP study compared with RP methods, the ability to explore preferences not accessible to RP methods, and the generally higher statistical significance of the results, have all contributed to this method of approach.

The development of microeconomic utility theory to incorporate the time duration of consumption and the compatibility of random utility-maximising models of travel choice with this theory have made the theoretical basis of study methodologies more robust.

Stated Preference (SP) offers a sample of survey respondents with hypothetical choices which involve trade-offs between time and money. This method allows travel choices to be presented to survey respondents in a controlled manner and, provided the choices can be conveyed with realism the survey and describes choices which are acceptable and with which the respondent is familiar, the majority of respondents can be expected to give rational useful responses. This method allows relatively cheap survey application methods, such as the postal return questionnaires used in the Netherlands studies made about 1990.

The main concerns of the SP approach in the past have been various biases which can or are suspected to occur in survey responses, but in the case of VTTS surveys however these concerns have been largely overcome. It is also important that the choices offered are as simple as possible, otherwise the respondent's capacity to rank or choose between various options becomes overloaded. This constraint can make it difficult to introduce several choice factors into a single survey design. Stated preference also offers the considerable advantage of being able to explore choice situations which either do not presently occur (although they can be easily visualised), or for which it is impractical to identify the choices in a field study.

In contrast, the conduct of **Revealed Preference (RP)** studies involves an interpretation of traveller preferences from actual behaviours which the analyst may not fully understand. The ever present risk is that important choice factors will be neglected, or that constraints on behaviour will fail to be recognised. Measurement of behaviour presents a problem, and there is the opportunity for the perceived levels of factors to differ from objective measurement, which itself may include some error. RP studies also experience difficulty in isolating the "traders" from the bulk of travellers, whose choice is firmly constrained to one or other option either by physical circumstance or ingrained habit. Consequently the number of useful responses is frequently much lower than is possible in an SP study, and the relative cost is high. The great advantage of an RP study is, of course, that actual behaviour and choices are being studied, so that the problem of people saying one thing but doing another is avoided.

RP studies rely on being able to identify situations in which travel time and money are traded, a prerequisite being that the cost variable should not be highly correlated with travel time. Contexts which provide these features are:

- Choice of transport mode, in which a slower mode is compared with a faster one, the money variable being supplied by a fare or for private car by the perceived component of vehicle operating cost. This is the most commonly occurring context and has been the main focus of RP studies over the years.

- Choice of route, in which a shorter route with a cost penalty, such as a toll road or bridge, is compared with a longer route. This is probably the second most "popular" type of RP study, but the number of such choice situations are more limited.

- Choice of speed, in which travel speed is traded against vehicle operating cost and safety. This has been used in some studies, but is possibly more demanding of knowledge of traveller perceptions of their risk exposure, cost of vehicle operation and time. There is no overt cost variable. This type of study provides the only example in New Zealand so far (Guria & Miller 1991).

A5.3 New Zealand Opportunities for Revealed Preference Studies

In the New Zealand situation, the opportunity for RP experimental studies is limited to a few situations of modal choice and one or two route choice options. Speed choice can be considered a third possibility, given that the trade-offs between time, perceived vehicle operating costs and perceived risk of accident can be effectively defined. RP study possibilities include:

- urban bus versus car in the main centres,
- a three way study of choice between suburban rail, bus and car in Wellington and, less probably, in Auckland,
- ferry versus bus and possibly car in Auckland,
- toll bridge versus untolled route choice in Tauranga.

A possible survey database for RP studies already exists in Wellington through the GATS study, in Auckland through the ATM studies, in Dunedin, and in Christchurch. These studies have used disaggregate models of generalised cost in which the travel choice factors, including time, are identifiable. The extent to which these studies can be used to inform about the VTTS from the coefficients against travel time depends very much on the nature of the data collected and how the models have been specified. This is discussed further in Appendix 16.

Because of the limited expectations from RP studies, judging from international experience, and the limited travel choice situations which they cover (primarily modal choice, involving all the self-selectivity problems and unique modal features of the urban centres in which each study is made), this method is expected to be only of limited use in providing behavioural VTTS appropriate to the majority of road projects within the scope of Transit New Zealand's project evaluation procedures.

An exception is the Tauranga Harbour Bridge, which offers a route choice study in which the "traders" can be fairly clearly identified (i.e. those living part way down the Mt Maunganui peninsula). An identifiable large flow of commuter traffic that travels to and from the Tauranga central area has the choice of paying no toll and travelling via Welcome Bay, or paying a toll fee and taking a shorter route.

A5.4 New Zealand Opportunities for Stated Preference Studies

Most of the project evaluations carried out for Transit New Zealand involve improvements to rural or urban roads which either provide a new shorter route or reduce delay without any route diversion. Thus this is the context within which empirical studies are most needed.

Because of possible differences in VTTS arising from journey length, urban/rural trip purposes, and disutility of congestion, SP studies in both urban and rural contexts would be useful.

The Tauranga Harbour Bridge offers the opportunity of combining an RP study with an SP study in an urban context. Respondents could be asked to choose either the bridge or the Welcome Bay route given higher or lower levels of toll respectively.

For rural highways, one of the main difficulties in designing an SP experiment is the selection of a realistic and neutral cost variable. In the MVA et al. (1987) study of long distance car travellers, a cost variable was introduced by way of a toll charge for a shorter route. This has some problems of realism, if there is no obvious location for such a road (if there is such a proposal, all manner of other preferences may be brought into play), and of positional bias by respondents who are opposed to the introduction of toll roads (seen as taxing the road user yet again). Such a study should also take into account trip time reliability and congestion effects in the design.

Opportunities to undertake SP studies of modal choice in the main urban centres, possibly as an adjunct to transportation planning studies. The SP method also offers the opportunity of testing preferences for new or significantly changed public transport modes, such as light rail transit and busways. However, considerable effort would need to be put into conveying the characteristics of any new mode to survey respondents. Audio-visual techniques could be considered.

A5.5 Recommendations

- If empirical studies are to be carried out in New Zealand, then the travel choice situations studied should be as closely aligned as possible to the nature of projects in which the resulting VTTS will be used.

- An opportunity for a combined RP and SP study using the Tauranga Harbour Bridge offers a possible site for a study of urban car commuters.

- An SP study of longer distance car travel on rural roads is also a possibility which is worth pursuing, although experimental design is likely to prove more difficult.

- Urban transport modal choice studies in Auckland, Wellington and Christchurch may be considered, although whether the travel surveys undertaken for transport demand model-building purposes will be able to provide the necessary data from which to infer VTTS would need further examination.

- Any special SP studies designed to elicit VTTS carried out in these centres would be expected to yield behavioural VTTS which could form the basis for resource VTTS in evaluation of urban transport projects in those centres, but which may have limited applicability in other travel choice contexts (such as in rural road appraisal).

A6. VALUATION OF WORKING TIME

A6.1 Introduction

This Appendix addresses the main theoretical issues relating to the valuation of time savings for travel relating to work/business purposes, by section in this Appendix, as follows:

6.2 Description and commentary on the basis of valuation currently used in the PEM.

6.3 Review of the research on the appropriate basis for valuing such time savings.

6.4 Examination of the issue of work which is undertaken during such travel time and how valuations should allow for this.

6.5 Examination of the extent to which travel time savings are used for productive work and how this might affect the valuations.

6.6 Examination of the issue of business travel which is undertaken during what would otherwise be leisure time, and how this affects the valuation.

6.7 Draws conclusions and makes recommendations.

At the outset it should be noted that our interest is in the well-being of society rather than that of specific individuals. Consequently, the value of time savings to society is considered rather than that to an individual or employer.

A6.2 Present Practice

The present PEM values for travel in work time (PEM Table A3.1) are based on the MPL approach, which had been used in the earlier Economic Appraisal Manual (TR9, Bone 1986) since the late 1970s.

The MPL is the gross hourly wage rate plus any employment-related costs borne by the employer. The data required to derive the MPL values are:

- gross hourly wage rates, for a range of occupational groups;
- other employment-related costs for each occupational group, including fringe benefits, accident compensation levy, and any marginal overheads relating to employment of an extra person;
- for different evaluation contexts, the proportion of work travellers and the distribution of occupational groups within total work travel.

In developing the PEM values, a number of assumptions had to be made which it was not possible to check. These included estimates of employer overhead costs and the distribution of occupational categories within the total work travel.

In relation to employer overhead costs, the amounts being paid in allowances, payments in kind and the administrative costs of employees are not well established. Some of the cost components currently in use are either based on very dated information or are little better than guesstimates. Hours of work are also not well defined: both the nominal and the effective hours of work are required to adequately convert between annual and hourly rates of pay and employers' costs.

Weaknesses are also found in the information on the occupational categories and incomes of working travellers and how the mix of occupations varies by road type and time of day. The present values date back to assumptions about in-work traveller occupations from 15-20 years ago, which, even then, were probably not very well established.

The current PEM approach also assumes that working hours are paid at an equal rate. For many travellers in the self-employed and professional categories, a proportion of in-work travel (not commuting) is undertaken out of business hours for which no additional remuneration is paid. In general, working hours have become more flexible, and this indicates the need for a reappraisal of whether the MPL approach is still tenable, or of how it might be modified.

Aside from these measurement issues, the theoretical basis of the MPL approach has been implemented in a fairly simplistic manner. No corrections have been made for the proportion of travel time diverted to productive work, therefore tacitly assuming that all time saving is productively employed. No correction has been made for in-travel use of time and the relative productivity of this time compared to time at the work site. The implication is that none of the travel time is usefully employed. Allowance for both these factors would tend to reduce the value of time savings to the employer.

Additionally, the preferences of the working traveller for time spent travelling versus time spent at the work site are also not addressed in the PEM formulation. If travelling is preferred then this will again depress the VTTS of working travel time.

A6.3 Valuing Business Travel Time

For commercial vehicle drivers, labour costs are measured by drivers' wage costs. Waters (1991) notes that AASHTO (1977) used four categories of truck size to establish drivers' wages costs, as the wage rates are determined by vehicle size. MVA et al. (1987) referred to a study by Mackie & Simon (1986, cited in MVA etal.), which examined the practices of transport operators in the context of the Humber Bridge, UK. The researchers concluded that the operators' valuation of travel time was of the order of the wage rate.

Waters recommends that the VTTS should be set at the employer's cost of an employee travelling, i.e. gross wages and benefits plus related expenditures such as overheads (p.42). MVA et al. noted that valuing business travel at the wage rate plus an allowance for overheads was not inconsistent with empirical evidence (p.169). Abelson (1986) indicates that the cost to the employer should be the gross rate inclusive of direct overheads associated with employment. These direct overheads (or on-costs) include employer payments of accident compensation and superannuation contributions.

Abelson differs from Waters, however, in that Abelson argues that indirect overheads such as office space, use of power, secretarial support, etc. should not be included as they would not vary significantly with savings in travel time (p.57). Hooper & Rimmer (1978) cite the Australian Commonwealth Bureau of Roads as having given an allowance of 10% above the wage rate to take account of overhead costs of employing labour (p.178).

BTE (1982) indicates that Fullerton & Cooper (cited in BTE 1982) were unwilling to accept that any material and quantifiable changes in overheads could be related to road improvements (p.5). It would seem logical that this view would hold in both the short term and the long term, i.e. that it is perhaps unlikely that adjustments could be made even in the longer term which would enable savings to be made in overheads. (The alternative might be to place a low valuation on the overhead savings, e.g. 5% of the overheads.)

Both Hensher (1989) and Miller (1989) indicate that costs to the employer should, in addition, be adjusted for taxation effects. Hensher notes that, in Australia, an employer must effectively pay out about 50% of any gain in productivity in the form of company tax. As a consequence, the value to the employer of an employee spending less time travelling and more time in productive work would only be about 50% of the full wage rate (p.226). With the on-costs representing on average 34% of pre-tax wages in Australia, Hensher argues that the value of business travel time to an employer would therefore be approximately 50% of 134, that is 67% of the gross wage rate (p.226). The value of the time savings to society, however, would represent the gross wage rates, because taxation receipts are returned in various forms to society. Taxation issues are discussed in more detail in Appendix 3 of this report.

Both Hensher and Waters point to a procedure to stratify the VTTS by the mode of travel chosen. To an extent, it would appear that the choice of mode chosen would be inferred to reflect the value of time to the self-selecting group of travellers. It would be apparent that the value of travel time will vary across business travellers depending upon their salaries, so a self-selecting bias to faster modes by those whose time value is greater might justify a stratified value of time by mode. This stratification issue is discussed further in Appendix 8 (A8.3) of this report.

On this issue, Hensher (1976) reports in TRR 587 (p.32) that the research team of the Commission into the Third London Airport raised the wage rate by 50% to obtain a value of time for business air travellers, on the basis that overhead costs and income-related payments of business air travellers are higher than those of business travellers in general.

In this context, the MVA et al. (1987) report noted that segmenting business travellers by income bands of £10,000pa suggested that the values of time savings in the top band (greater than £20,000) were 70% higher than the values in the bottom band. MVA et al. warned, however, that the sample size was small (p.151).

A6.4 Work Undertaken while Travelling

The VTTS for business travellers lies in the traveller's use of the travel time saved for an increase in productive output. In reality, of course, a traveller may be able to use some of the travel time as work time, particularly when full attention need not be given to the act of travelling itself. This is particularly the case for bus, train, taxis and aeroplane travel, compared to car travel where full attention to driving should be required if the business traveller is driving himself. (However, note the increasing use of car-phones for conducting business while on car trips.)

Theoretically, in the extreme, a traveller might be able to make use of all travel time in productive output. In this case, a travel time saving would have no value as production would not change. In general, however, production levels while travelling would normally be expected to be considerably less than the average for working time, owing to lower levels of productivity and owing to not all the travel time being devoted to production.

Bradley & Gunn (1990), in their study in the Netherlands, quote the Hensher formulation for the value of an hour of travel time saved to the employer as being equal to:

PVWT x (%W - %TW x %PTW),

where *PVWT* = the productive value of an hour of work time;
%W = the percentage of travel time savings diverted to work;
%TW = the percentage of travel time used for work;
%PTW = the relative productivity of work during travel.

In the extreme therefore, if *TW* and *PTW* are 100% each, then there will be no value on any travel time saved (p.9).

Bradley & Gunn's study revealed that the percentage of business travel time spent working was as follows:

- about 11% for travellers using the train;
- 3% for travellers using the bus; and
- 2% for travellers using a car.

The 1977 Travers Morgan study for the UK DoT reported that 40 of the 60 respondents in their survey sample said that they did use road travel time for work purposes and that it was productive. If Bradley & Gunn's research is consistent with Travers Morgan's research, it would suggest that the proportion of car travel time spent working would be very low. This may be a logical conclusion particularly for single-occupant cars where attention should necessarily be largely focused on driving the car.

A6.5 Time Savings Directed to Work

MVA et al. (1987, p.60) undertook an activity-based research project which examined the implied trade-offs between time spent on different activities. They found that people tended to alternate during the day between more demanding/strenuous activities and quieter/more relaxing ones. As a consequence, any time saving may be spent on an activity with the opposite characteristics to that of the trip purpose. Following this through logically, however, it might well be the case that business people may seek to behave similarly during days when no travel is involved. If this was the case, then the output forgone might not be as great as implied by some researchers. Consistent with this, it might be argued that the reduced productivity and work intensity in the period spent travelling might well provide the opportunity for higher productivity in normal work time. This would imply that the measured productivity in periods of travel might be understated and the extra productivity resulting from any savings in value of travel time would be overstated.

When considering travel time, Bradley & Gunn (1990) found that the relative productivity of any time devoted to work was about 90% relative to usual working conditions, irrespective of the mode (p.9). Waters (1991) questions, however, whether small time savings could be used productively (p.42). In the long term, however, it would seem likely that business travellers would be able to adjust to reduced travel times and therefore divert that time to more productive uses.

Waters recommends that the value per person for light vehicle time savings should be between 55% and 100% of the cost to the employer, depending on the proportion of work time saved which would be translated into increased output. Waters notes that ... *"most studies (implicitly) assume that all work time savings is used productively ...."* (p.43). Obviously, if travel time savings are not used productively, then the value of those savings should be reduced.

A6.6 Business Travel Undertaken in "Leisure" Time

MVA et al. (1987) notes that much of the longer distance business travel involves travelling in time that would normally be regarded as the employee's own and is not directly paid for by the employer (p.60). In this case it would be inappropriate to value the travel time savings at the cost to the employer rate. Rather, it should be valued at the personal rate, which is typically a lower value. MVA et al. also note that Hensher has argued that the valuation of business travel time should include the cost of that personal time to the traveller as well as the defined work time to the employer.

Very little other research has been undertaken on the proportion of business travel time which is undertaken in the employee's own time. The 1977 Travers Morgan study did find, however, that one-fifth of business travellers interviewed in the survey claimed to be travelling in non-work time. It should be noted, however, that some of the travel in non-work time will be for leisure's sake rather than a "sacrifice" for the employer. In such cases the VTTS might be expected to be very low.

The VTTS while on business will also be a function of the extent to which the travelling occurs during the employee's own time and, according to the extent that this occurs, the value of the savings will be reduced. Similarly, if some of the travel time is productively used, then the increase in production (and thus the value of the savings) will be less than if all travel time is unproductive. Offsetting this effect is that working while travelling is often less productive than normal production and so, other things being equal, the value of travel time savings would be greater.

In many cases the distinction between "work" and "leisure" time will not be clear-cut. If a certain amount of travel outside formal business hours is an implicit requirement of the employee's position, then this time is effectively not leisure time. However, in such cases any time savings are most likely to be used for "leisure" purposes, and hence the value of leisure time reflects the opportunity cost of the time savings.

A6.7 Conclusions

The value of any savings in business travel time is the sum of the utility of the savings to the employer plus the savings to the employee. Empirical studies show that these together roughly coincide with the marginal cost of employment to the employer. These marginal costs will include direct labour on-costs such as superannuation payments, long service leave, and other employee benefits. Account would also need to be taken of any overtime payments made.

The rejection (or very low valuation) of any indirect overheads (such as secretarial staff) reflects the scepticism that time savings are normally sufficient to flow through into reductions in such overheads. The scale of business travel and/or travel time savings would most likely need to be very great to achieve any measurable impact on these overheads, so they are usually ignored in calculations.

Hensher (1989) notes that productivity gains resulting from time savings will effectively be taxed at the margin and therefore the benefit to the employer would be reduced by the marginal rate of taxation. Even if the benefit of the time savings to "society" was taken rather than the benefit to the employer, the taxation effect would act to reduce the desire to achieve output gains at the margin (though this might be regarded as a very marginal/theoretical situation, at least in the short term).

The foregoing review suggests that there is a case for segmenting valuations of working time by mode. First because business travellers will be self-selecting, so that travellers on higher salaries will tend to have a higher cost of time and are therefore likely to go on faster modes, and second, the level of work and productivity which can be achieved is likely to vary by mode. Train and air modes are shown to induce higher production and work efficiency than travelling by car.

Waters (1991) notes that, while it is commonly assumed that the value of work trips is equal to the employee's cost to the employer, little empirical work has been undertaken. Also little research appears to have been made into confirming the consistency of the VTTS across transport modes. For instance, if train travel is associated with greater potential production levels, then for similar comfort levels, calculation of the differential travel costs and production levels could be used to derive a value for train travel time.

As noted in Section A6.5, however, some apparent down-time may enable greater levels of productivity in normal working conditions. This would imply that the benefits of travel time savings are overstated. Consistent with this (and it is unclear why), the level of productive time on a train in particular – estimated by Bradley & Gunn to be 11% on average at a productivity rate of 90% – is so low given that the mode is relatively conducive for working (certainly on longer distance trips).

In summary, the value of business travel time savings to society is commonly based on the employee's gross wage plus direct labour on-costs. Indirect on-costs may also be regarded, in the longer term, as variable to some degree. That "base" value of time savings will then need to be varied to account for the extent to which:

- travel time saved is subsequently used productively,
- business travel is undertaken in leisure time,
- some travelling time is used productively (though not necessarily at full effectiveness).

VTTS will also need to be varied across travel modes to account for variations in travelling time productivity achievable across modes and because choice of mode tends to be associated with the employee's salary (travellers on higher salaries tend to go on faster modes).

A6.8 Recommendations

Travel time savings relating to people travelling on business purposes are a substantial component of total travel time savings from typical road improvement projects and therefore reliable estimates of VTTS for such travellers are of considerable importance. As described in this appendix, present methods may be deficient in several significant respects, and the resultant VTTS may well be over-estimated.

Three main areas would benefit from further research in the New Zealand context:

(1) Market research on the extent to which savings in business travel time will result in increased work production, and/or reduce employer costs, and on the extent to which the savings will result in increased leisure time. This research would need to address at least the following three aspects:

- the extent to which any travel time savings would be spent in working or in leisure;
- the extent to which productive work is undertaken during travel, in terms of the percentage of travel time spent working and the relative productive efficiency of this time;
- if it is reasonable to value any saved time used for working at the average cost of labour (including any variable overhead components), or at a lesser rate than this.

The extent of these three effects can be expected to differ by business sector/employee type, transport mode and time of day, and partly because of self-selectivity effects among travellers. The research would require in-depth interviews with business travellers sampled across various business sectors/ employee types.

(2) Research into the labour overhead proportions (both direct labour on-costs and indirect variable overheads) for different industry sectors/employee types. The research would involve interviews with selected companies in a range of business sectors.

(3) Research into the income levels of people who travel on business (by industry sector etc.) and their proportional representation in the traffic stream: this will vary by mode, time of day, type of area, etc. This research is best covered under the research programme relating to Representative Travel Data (refer Appendix 15 in this report).

In areas (2) and (3) in particular, little use can be made of international data and therefore New Zealand specific surveys and research are highly desirable. In area (1) it would probably be more feasible to make some use of overseas research, although the research available does not appear to be adequate. A market research project on this area in New Zealand may well be worthwhile.

A7. VALUATION OF TRAVEL TIME SAVINGS RELATING TO COMMERCIAL VEHICLES

A7.1 Introduction

As well as allowing for travel time savings to vehicle occupants, the present PEM also allows for the effects of travel time savings on vehicle costs (PEM Table A3.2).

For commercial vehicles and cars (including taxis) used for business or commercial purposes, the value of vehicle time per hour that is used in PEM is calculated from the annual standing charges (in resource cost terms) divided by the estimated annual hourly utilisation. The same approach was used in NRB TR9 (Bone 1986). Effectively this assumes that any time savings will result in greater utilisation of the vehicle and, in particular, that commercial fleet sizes will be reduced (pro rata) as a result of the time savings. (Conceptually, such cost savings might be better treated as a component of vehicle operating costs, variable with time, rather than travel time costs. In any event, the treatment of vehicle savings needs to be consistent and coherent between the time savings and vehicle operating savings categories.)

In the case of vehicles used for private purposes (primarily cars), a zero value of vehicle costs per hour is assumed on the grounds that time savings, in general, will not result in additional vehicle utilisation or reductions in vehicle numbers.

Similarly in the case of buses and coaches, the PEM assumes that no utilisation improvements will result from any time savings, and therefore a zero value for vehicle costs per hour is used. This is obviously open to argument.

No allowance for the costs of freight time is included in the present PEM (although PEM Table A3.2 implies that freight time is included). Since publication of PEM some further examination of this topic has been undertaken for Transit New Zealand. Beca (1992) recommended to Transit New Zealand that the PEM should include some allowance for the delay costs of freight carried by commercial vehicles, while recognising that the suggested allowances were very approximate and would require further investigation.

This Appendix 7 reviews the limited information that is available in relation to commercial vehicle transport on:

- the ownership costs of the vehicle,
- the opportunity costs associated with transport of the goods.

The valuation of the driver's time costs is covered separately (Appendix 6).

A7.2 Vehicle Ownership Costs

In relation to the ownership costs of commercial vehicles, Waters (1991) notes (p.75) that AASHTO (1977) makes no allowance for changes in ownership costs associated with changes in travel time. He suggests that ownership costs should be divided by less than the total hours in a year to recognise that a truck and trailer cannot be used 100% of the time (p.78).

For bus operations, Walters suggests that the ownership costs of a bus should also be accounted for in estimating the VTTS (p.72). Opportunities are likely to be limited for exploiting the time savings achieved on coach operations and, to a lesser extent, on local bus operations, because of the time-related demand for the services. As a consequence, the reduction in ownership costs of buses and coaches seems likely to be less than proportionate to any savings in travel time.

The UK DoT COBA Manual notes that:

> *... increased speeds yield potential savings in the numbers of working cars, commercial vehicles and public service vehicles which operators need to provide. An estimate of this effect is included in the VOC. ...*

A7.3 Freight Costs

Abelson (1986) acknowledges the opportunity costs associated with goods while in transit. A faster time between production and consumption of goods reduces the interest cost associated with the transition between production and consumption. Savings in interest are a function of the value of the goods being transported, the amount of time saved and the opportunity cost of capital, i.e. the interest rate (p.56).

According to Abelson, reduced transport time will also lead to a saving in terms of damage to goods and depreciation of the goods themselves (p.56). Perishable goods will have a high depreciation value as their value decreases rapidly with the passage of time (Waters 1991, p.21). Waters postulates that such goods have a value which is inversely related to their length of time in transport (p.79).

In the case of refrigerated goods, a time-based component of operating costs will relate to the refrigeration unit, additional to the vehicle ownership and goods opportunity costs. This component will need to be allowed for (either within the time values or, maybe more appropriately, within the operating costs). Also, any fragile goods are likely to deteriorate as a result of rough roads, and allowance also needs to be made for this effect within the operating cost functions.

For many products, however, where the depreciation is not significant, the cost of the transport time will not be anything more than the opportunity cost of the money which is tied up in the goods (Waters, p.79). It may be, suggests Waters, that the opportunity cost of money may be no more than 5 to 10% of the VTTS based on the driver's wage alone. Firms nevertheless aim to reduce their stock holdings at the factory or wholesale/retail outlet because these incur an opportunity cost (forgone investment interest) on stock held in excess of immediate requirements. Consequently, firms have increasingly adopted just-in-time delivery of stock (Waters, p.79).

A study by Blauwens and Van de Voorde (1988) examined the choice of ship-barge versus truck movements in Belgium. They concluded (p.85) that the annualised value of time for truck traffic was about 74% of the value of the goods compared to, say, around 10% for the value of goods when considering money cost alone. They also quote the valuation on an hourly time-saving basis, which is 0.0000848 times the value of the goods. For typical goods with costs of $5000/tonne, this represents $0.40/hour per tonne. They consider this to be plausible if important side aspects, such as goods deterioration, costs of shortage of stock, fines for delay, etc., are taken into account. Waters comments that this value is higher than might be expected (p.79).

Just-in-time stock holding places a heavy reliance on fast, reliable delivery. As a consequence, there may be a premium on transport time in excess of the opportunity cost of capital. The premium on just-in-time freight can be very high when the goods are part of a larger production–distribution system. However most of this premium is considered to relate to the reliability of delivery rather than to the mean travel time. Senna (1991, p.265) notes that reduction in travel time variability needs to be considered as one of the benefits of travel time savings. The desire to reduce variability is consistent with the evidence for the value of time in general, which indicates that a value placed on a unit of travel time lost is much higher than on a unit saved (Cheung et al. 1989, p.238). In essence, the solution to the variability is to build in considerable potential slack time, which in effect means to lengthen the journey time. Issues of travel time variability/reliability are covered separately (Appendix 2 in this report).

A7.4 Conclusions

In the case of travel time of commercial vehicles, three main elements of potential savings result from reduced travel times:

- Savings in driver (and other occupants) time: this is covered in Appendix 6.
- Savings in vehicle ownership costs.
- Savings in opportunity costs associated with the goods while in transit.

In addition, any other time-related vehicle operating costs (e.g. for a refrigeration unit) need to be allowed for in evaluation, either in the travel time functions or the vehicle operating cost functions.

For vehicle ownership costs, the main issue is whether and to what extent time savings may be usefully exploited by redeploying the vehicle. The research in this area mostly indicates that in the case of time savings for goods vehicles, the vehicles may generally be redeployed, although not necessarily pro rata. Time savings for private vehicles would rarely lead to vehicle redeployment and therefore to savings in vehicle stock. Very little research appears to have been carried out in the case of buses, and our judgement is that the potential savings in vehicle stock might well be significant, although usually well below pro rata to the time savings.

A review of the PEM assumptions on vehicle ownership costs may therefore be appropriate in two respects:

- For goods vehicles, to review whether the present assumption of pro rata vehicle savings is reasonable.
- For buses, to review whether some allowance should be made for vehicle savings.

For freight opportunity costs, clear distinction needs to be made between the reduction in the average transit time for goods and the reduction in variability in transit time. The costs associated with the goods relate to the monetary opportunity cost of the value of the goods, which tends to be associated more with the average transit time. By contrast, for goods such as perishables and just-in-time stock holding, it is the variability of transit time (reliability of service) that imposes the cost (and thus potential savings) of travel time.

The issue of reliability of travel time is addressed in Appendix 2 of this report. For the opportunity costs associated with average transit time, these clearly should be ascribed a value, albeit that this will be low relative to other cost components. Our research so far has not resulted in any better estimates than those given earlier by Beca (1992), but a more extensive survey of the international literature might provide further information from other studies.

A7.5 Recommendations

Given the paucity of international research on these issues and given that any international findings may not be readily transferable to the New Zealand situation, VTTS relating to commercial vehicles is a topic on which local research may well be worthwhile.

A New Zealand survey of truck operators and users of freight services should be undertaken, to investigate the effects of potential travel time savings on:

- Driver/staff utilisation,
- Vehicle utilisation and fleet requirements,
- Freight inventory/stock-holding costs - in general and for perishable cargoes in particular.

The same survey might usefully also cover the implications on costs of unreliability of travel times.

A separate small survey of bus/coach operators may also be warranted, to establish the impacts of potential travel time savings on fleet requirements.

Following these surveys, the present PEM values relating to vehicle time costs, freight costs (not included now), and possibly commercial driver/staff costs, will need to be revised.

A review of PEM is also desirable to ensure that it covers consistently and comprehensively (under either vehicle operating costs or time costs):

- Vehicle ownership/depreciation costs,
- Time-based vehicle operating costs (e.g. for refrigeration units),
- Freight damage, caused by rough roads, etc.

A8. EVIDENCE ON BEHAVIOURAL VALUES OF TRAVEL TIME SAVINGS

A8.1 Background

Before 1991, the Transit New Zealand project evaluation procedures recognised only a single value for non-work travel time savings applying to all modes of transport, person types, times of day, and non-work trip purposes. This non-work value was nominally set at 25% of the average gross wage rate for full-time employed persons.

The studies in the 1980s sponsored by the UK DoT (MVA et al. 1987), and the results from empirical studies in Australia and the USA, greatly increased the information available on the behavioural VTTS. The UK researchers were sufficiently confident in their results to recommend the adoption of a range of time values differentiated by income group, transport mode and employment status. However, while there clearly were differences between the VTTS for users of different modes, the different empirical studies showed a considerable range of results which could be attributed to the exact circumstances of each study (the available choices, nature of the modes, urban/suburban/long distance context, constraints on travellers time, regional differences, etc.).

In the 1991 issue of the PEM, Transit New Zealand chose to recognise certain differences in non-working VTTS, namely those between car drivers and car passengers, between car travellers and bus users, between seated and standing bus passengers, and between car drivers and pedestrians and cyclists. The background to these changes is discussed in Section 2.3 of this report.

Studies of travel choice carried out during the 1980s have provided a much expanded resource of empirical results on behavioural values of time saving than was previously the case. These studies were reviewed by Beca (1987) for the Urban Transport Council and by Miller (1989) for the National Roads Board. Internationally, reviews have been made by Hensher (1989), Bates & Glaister (1990), and Waters (1991).

The main findings on the factors influencing behavioural VTTS are discussed in this Appendix 8 under the following headings:

- Self-selectivity effects (this is dealt with first as its implications for the interpretation of any empirical study are of considerable importance (A8.2)
- VTTS and income (A8.3)
- Car drivers and passengers (A8.4)
- Public transport modes (A8.5)
- Establishing modal values of time (A8.6)
- In-vehicle comfort (A8.7)
- Non-work travel purpose (A8.8)
- Person type (A8.9)
- Local versus long distance travel (A8.10)
- Trip time of day (A8.11).

Further, congestion and reliability is discussed in Appendix 2; VTTS for travel in working time in Appendix 6; and walking and cycling VTTS in Appendix 10, of this report.

A8.2 Self-Selectivity Effects

A number of the VTTS studies use mode choice as their basis for derivation of values. The MVA et al. (1987) study included several mode choice sub-studies. An important methodological problem they identified (in retrospect) was that of "self-selectivity" of travellers. This is best explained as travellers gravitating to that mode of transport which suits their time constraints for the journey being undertaken, as well as any other preferences that move them to choose one mode rather than another. Thus fast and reliable (and usually more expensive and more comfortable) modes tend to attract those travellers with time constraints, who therefore have a high VTTS. Slower or less reliable (and usually cheaper and less comfortable) modes tend to attract those with lesser schedule constraints and therefore lower VTTS. The extra comfort and convenience of the faster modes *should* be an offsetting benefit to travellers, depressing the VTTS, because, if in-vehicle time is more satisfying, there should be less desire to reduce it. But in practice the original mode choice has been made by high time-value travellers and the comfort effect is submerged.

Those at the boundary between choosing one mode or another may not be typical of either group, so the VTTS resulting from their choices are not necessarily representative of the average within-mode VTTS for either mode.

Thus, behavioural VTTS associated with a particular mode of transport do not depend solely on the characteristics of the mode in question, but also on the competing modes available for the journey. If only car and bus are available, bus passengers will exhibit on average a certain VTTS. If a competing mode, say a light rail service, is introduced and the travellers redistribute among the three modes, the bus passengers now have a different average VTTS than before.

The conclusion is that, if modal values are to be used, separate values may be applicable for within-mode VTTS for "captive" travellers compared with those who are in the market for a change of travel mode, and the average VTTS for each group will be modified if another mode is introduced. As, in New Zealand at least, the car has the lion's share of the market, introduction of new modes is not likely to affect the average VTTS of car travellers to any large degree. Most modal choice situations involving public transport are a choice between car and local bus. It is possible that a generally applicable mean VTTS can be established for captive bus passengers, and similarly for captive suburban train passengers.

A8.3 VTTS and Income

Figures A8.1 (MVA et al. 1987) and A8.2 (Bates & Glaister 1991) show the relationships between VTTS and income from the UK and Netherlands studies, with evidence from earlier work by Quarmby (1967) and LGORU (Local Government Operations Research Unit). The evidence is now clear that VTTS rises with income but at a less than proportional rate, which suggests that any percentage value (such as 25% or 40%) is only applicable at some mid-range income, but will be greater at lower incomes and lesser at higher incomes.

At a household income of £3,750, the UK study results cluster round 3.5 p/minute (£2.1/h) which, assuming 2000 working hours/year, is around 90% of the wage rate. At the other end of the scale, at a household income of £25,000 the VTTS is around 7.0 p/minute (£4.2/h) or 34% of household income. The Netherlands study, for non-work time, indicated VTTS increasing more slowly with income. For example, values were approximately 100% of average household hourly income at low incomes increasing gradually to 20% at high incomes.

Figure A8.1 Relationship between values of time and income, UK.
Facsimile of Figure 2 from MVA et al. (1987)

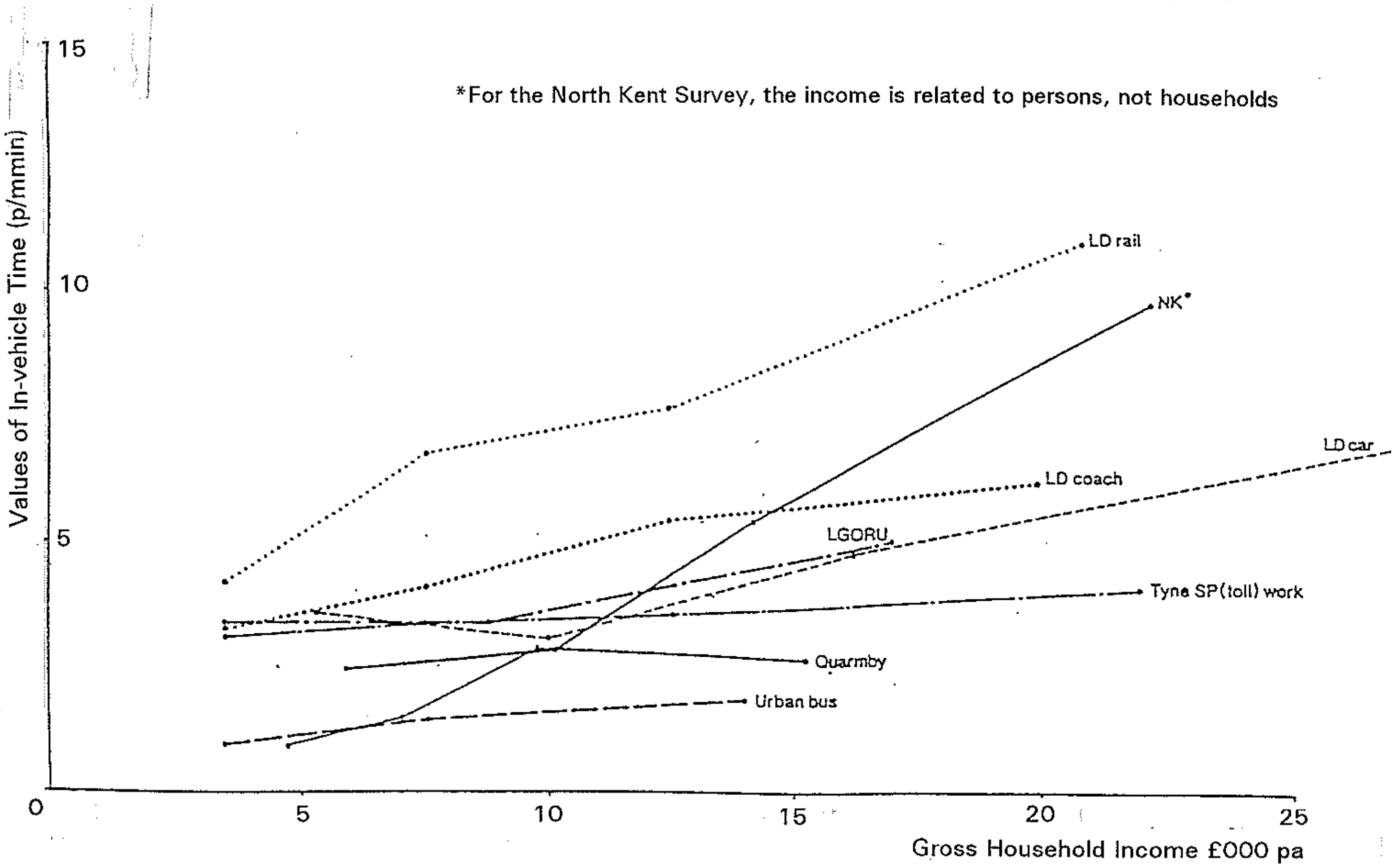
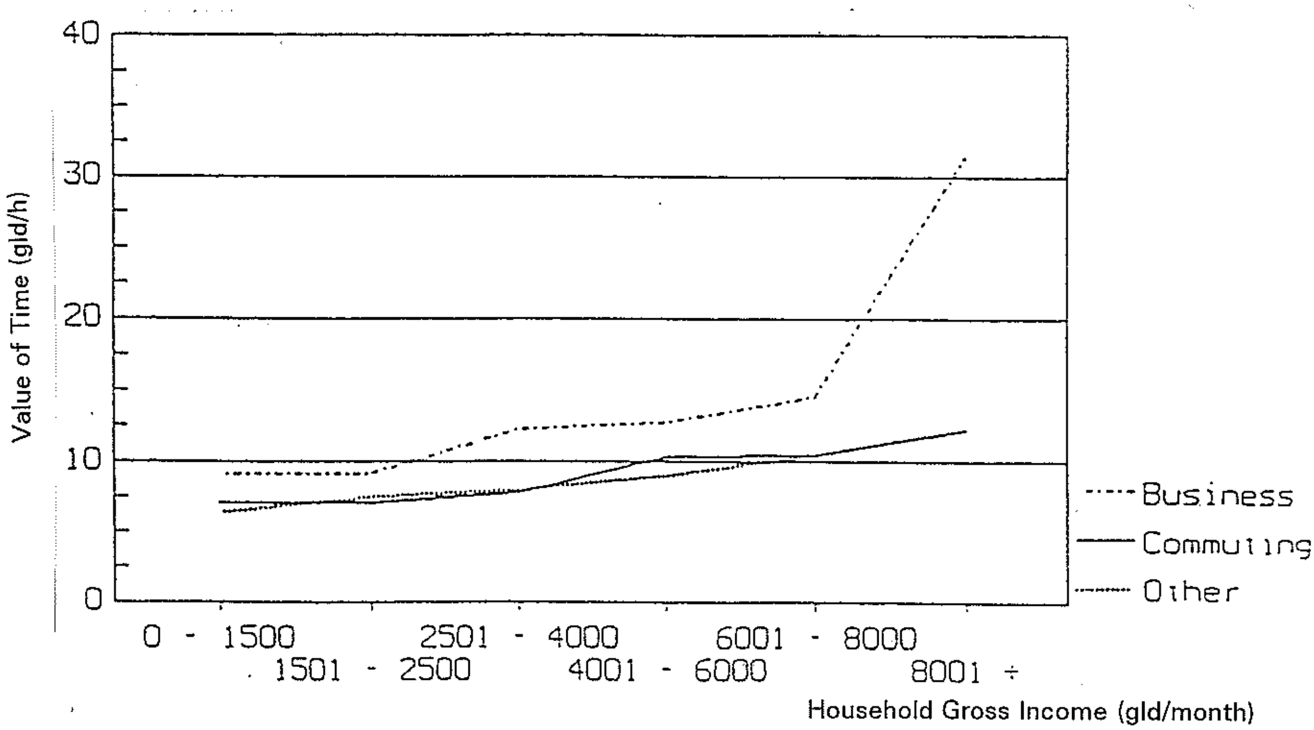


Figure A8.2 Relationship between values of time and incopme, Holland.
Facsimile of Figure 3 from Bradley & Gunn (1991)
gld = guilder ; mo = month



While the majority of studies have found a rise in VTTS with income, there are one or two exceptions. Waters (1992) cites Beesley (1965) and Mohring et al. (1987) as finding VTTS to increase *more* than proportionately with income. However these appear to be isolated results.

One implication of these findings is that it is important to identify income stratification in any empirical study and to have income data in typical evaluation contexts, so that appropriate adjustments can be made. This is also important when comparing the results of empirical studies, particularly across countries, when income becomes a convenient means for reducing values to a common basis.

The variation in non-work purpose VTTS with income appears to be relatively minor over much of the income range. In practice therefore, provided an appropriate weighted mean which characterises the income distribution of the travelling public is used, then a single value may be the most practical solution. A single value also may defuse part of the "equity" argument. This appears to be the approach being taken by AASHTO (Chui & McFarland 1987).

A8.4 Car Drivers and Passengers

Table A8.1 reproduced in this Appendix 8 is a facsimile of Table 1 in Bradley & Gunn (1991) and lists the findings of a number of empirical studies. These findings are taken from the original research of Bradley & Gunn and of Miller (1989) and Waters (1992). The studies can be categorised in various ways - by country, form of empirical study, urban/rural context and trip distance, trip purpose, revealed and stated preference method, and by year. Each of these factors could potentially have a substantial effect on the result so the wide scatter of findings should not come as a surprise. The VTTS also have to be converted from the original currency, indexed against a measure of inflation and then, for convenience, can also be expressed as a percentage of the average wage rate, where this can be identified.

Waters' (1992) review indicated that 22 out of 33 study results for car commuters lie within the range 30% to 70% of the wage rate, with four results below this band and seven results above. Waters found a simple mean of 47% from the various studies, concluding that representative VTTS for car commuting lies in the 40% to 60% range, with North American results at the higher end. Miller (1989), who used a smaller selection of studies, determined a simple mean of 62.5% of the wage rate.

In contrast, studies based in the UK, the Netherlands and Australia yielded values for car commuting which, as a group, are generally lower than those from the North American studies.

One matter which is discussed in MVA et al. (1987), but which has received little further attention in the literature, is whether the WTP values from studies of car driver behaviour or stated preference *include* the value of passenger time. If the driver is expressing his/her own preference, then it is reasonable to add in the respective passenger values to establish a VTTS for the occupants of the vehicle. This is what happens in practice. However, if the driver is already including a partial or full valuation of passenger time savings, then to add passenger time would be an over-estimate. This remains a matter of some ambiguity in route choice and speed choice surveys.

In a survey of long distance car travel, the UK studies indicated higher driver VTTS in cars with passengers and, by interpolation, a 15% to 20% increase per additional passenger was suggested. However for a study on shorter distance commuting, the driver VTTS was 5% lower when a passenger was present. Overall, the long distance study results were believed to have greater weight and, that for behavioural application, the driver value would correctly account for route choices by vehicles.

MVA notes an important implication for evaluation. If it is decided to base evaluation values on WTP, then the behavioural values for the vehicle are an appropriate measure. On the basis of this study this means that the driver value should be used alone. If, however, an "equity" value is to be used, then it should be applied in proportion to occupancy. The choice is between a common value for all modes multiplied by an occupancy factor; or separate values for each mode; with an application of an occupancy factor only in the case of public transport.

Hensher (1989) found car passenger VTTS to be some ⅔ that of car drivers for urban commuting. This finding has subsequently been recommended by Miller (1989) for application in New Zealand. Waters (1992) also adopted this finding.

A8.5 Public Transport Modes

Despite the self-selectivity problems inherent in mode choice studies, the MVA et al. (1987) research found such large differences in modal VTTS that they considered these differences should be recognised in practice. However they stopped short of advising how far behavioural values should be adopted or modified for project evaluation. The study betrayed some lack of confidence in its results, which showed urban local bus VTTS at 25% of the wage rate, by arbitrarily increasing its recommended value to 40% of the wage rate. Rail and express coach services were found to have similar VTTS to car drivers. The UK DoT (1987) decided not to apply modal values at all, ostensibly on the grounds that self-selectivity effects made it difficult to recommend firm values, but possibly also because to do so would reduce the benefit estimates for public transport projects.

In Australia, Hensher (1989) determined an appropriate behavioural value for bus passengers to be A$3.50/h, equivalent to 30% of the wage rate. In this case rail passengers demonstrated a *lower* value than bus. This adds emphasis to the fact that the basic description "bus", "rail", etc. is insufficient to conjecture an average VTTS for the passengers on a public transport mode. The speed of the service in delivering passengers from origin to destination, the reliability and to lesser extent comfort and fare cost, together with the comparative features of competing modes all influence the VTTS of riders.

The recent Netherlands studies (Bradley & Gunn 1991) found average VTTS by bus or tram to be approximately 54% of that for car users, and for train travellers to be approximately 74% of that of car users. Although there was some variation by income, in all income groups the same ordering of modes in terms of VTTS (car/train/bus) was found. The researchers in this study attempted to identify the separate mode-specific effects of: in-vehicle (dis)utility of travel time; self-selectivity effects; and perceptions by non-users of the rejected mode. They found that for commuting and business trip purposes, the attributes of the chosen mode dominated the other two effects. However this was not so for the "other" trip purposes category, for which the self-selectivity effect appeared to dominate.

A8.6 Establishing Modal Values of Time

Because modal attributes range so widely, walking has been suggested to be the most stable "base" for VTTS against which differences for other modes may be compared. Unfortunately walking as a main mode of transport has not been the subject of study and, where it forms a secondary access mode, walking times and distances are often approximated from assumptions regarding average access distance to the transit stop and walking speed. The VTTS for walking has also been found to vary greatly according to age of the traveller, being much higher for the elderly than for young adults. So care must be taken in establishing a base. Alternatively VTTS for car drivers, which has received more study than walking, could form the base against which VTTS for other modes are expressed. This appears to be the most practical solution and is the base which was chosen to express the results in the most recent Netherlands research.

It has also been suggested that, rather than trying to typify modal characteristics and VTTS, modes should be considered more in the abstract and the effect on VTTS of general attributes used as modifying factors on a base VTTS. Modal attributes can be separated into those that are largely independent of time, such as the need or otherwise to walk and wait for the transport service, and those which correlate with in-vehicle time (the "comfort and convenience" factors) and the overall journey speed. Again a degree of success has been attained in pursuing this approach in the UK and Netherlands studies.

When considering VTTS by mode of transport obtained in international studies with a view to adapting these for use in New Zealand, a comparison could consider the following:

- Characteristics of the transport mode, i.e. reliability of arrival and journey time; speed; length of trip; in-vehicle comfort; and price relative to alternative modes.
- Socio-economic characteristics of the transport users.
- Other choices available to the transport users, and the effect on market shares.
- Whether the VTTS is to be applied in modal choice situations or for changes in travel time within a particular mode of transport.

A8.7 In-Vehicle Comfort

Apart from reliability and road congestion effects, which are discussed separately, the value of transferring time from travel to other uses should be determined in part by in-vehicle "comfort". For the private car, one might anticipate that in-vehicle conditions are relatively uniform within countries, and to a large extent between countries. In contrast for public transport modes, there is scope for wide differences in the interior quality of the vehicle, e.g. seating type and ability to obtain a seat; internal environment, e.g. air quality, soundproofing, lighting; compatibility with and behaviour of fellow travellers; smoothness of ride; ability to engage in other activities while in transit; and other conditions.

In theory, a high standard of comfort should depress the VTTS and vice versa. However these effects tend to be submerged by the correlation between high standards of comfort, journey speed and cost, which attracts travellers with a high VTTS to high quality transport modes. If such factors are ignored then the qualities of public transport modes cannot be readily included in an economic evaluation.

Published empirical studies appear to have seldom investigated WTP for in-vehicle comfort on public transport modes. For standing passengers, Miller (1989), on the basis of Algers et al. (1985), recommended a VTTS of 250% the wage rate, or six times the base passenger value. How far the expectation of having to stand is built in to transit modal VTTS is unclear and this may explain some of the variation in results.

Bates & Glaister (1990) comment:

> *... recent work known to the authors .. has indicated that values of time do rise consistently as the probability of getting a seat falls, and that a reasonable assumption is to assume that the value of time standing in public transport is equal to twice the standard in-vehicle time, suggesting a parallel with walking time, while even higher multipliers may be appropriate for "crush" conditions.*

The same authors also cite a study by Van De Waard (1988) in which a 10% difference in the value of saving in-vehicle travel time between a rapid transit mode compared to urban bus or tram was attributed to comfort differences.

A8.8 Non-Work Travel Purpose

The evidence regarding VTTS differences between work commuting and other trip purposes in still conflicting. For recreational travel, in particular, theory would indicate a lower VTTS than for work commuting. Hensher (1989) finds a substantially lower VTTS for urban social/ recreational trips by car compared with private work commuting, by a factor of 0.6. However this finding appears to be exceptional, with Miller (1989) reporting differences of less than 15% between commuter and leisure trips for 15 studies, and the UK research being unable to detect any consistent differences. Only for rural long distance trips have some consistent findings of lower VTTS, by around 10 to 20%, been made.

The Netherlands study found "other leisure" purpose VTTS to be some 35% lower than for work commuting, although the composition of the sample in regard to age, available free time, and employment status explained most of the variation. The only other finding related to non-work trip purpose was a 20% higher VTTS for education and 10% lower value for shopping/personal business compared to all other (social/recreational) non-work purposes.

Waters (1992), reviewing the evidence for a difference between commuting and other non-work travel, concurred with Miller (1989) that, while the dispersion of VTTS among studies of recreational travel was greater than for commuter travel, overall there was insufficient evidence to recommend a separate VTTS for recreational travel. The wider spread of results could be explained by the variety of recreational pursuits included, from those that required adherence to a time schedule to those in which the journey itself is the trip purpose.

A8.9 Person Type

The recent studies in the UK and Netherlands clearly distinguish a difference in non-work VTTS according to person type. Much of this variation is attributable to the availability of "free time" and the number of fixed constraints in personal time schedules. Those with flexible time schedules and a large amount of uncommitted time tend to exhibit lower VTTS than those with busy fixed schedules and little available free time. These personal scheduling constraints are to a greater or lesser degree associated with age, sex, employment and family status.

MVA et al. (1987) found a clear pattern that retired persons, and to a lesser extent students, have lower values of time than work commuters (by 15 to 40% depending on mode), while those with variable hours of work have higher values. Recommended differences were 25% below the base value (applying to full-time workers with fixed hours) for retired persons and 20% below for students.

The same study also found that, if a two person household was taken as the base, then VTTS should be increased by 10% for those living alone and reduced by 10% for households of three or more members.

The Netherlands study (Bradley & Gunn 1991) considered person type differences in some detail, and Table A8.1 is copied from their paper. The framework suggested for establishing a behavioural VTTS for any one situation is to take the base value for the income group and then apply modifying factors as linear additions or subtractions (the effects are not multiplicative). For work commuting, notable differences lie in: household composition; part versus full time employment; sex; age group; and personal free time. For other non-work travel the differences are less marked.

A8.10 Local versus Long Distance Travel

Hensher (1989) notes that little empirical research has been undertaken in the context of non-urban travel, and recommends that long distance inter-urban travel should be distinguished from local rural and metropolitan travel. From mode-choice studies associated with the Australian Very Fast Train project, Hensher derived a value equivalent to 68% of the wage rate, compared to 36% for urban commuting.

This Australian recommendation does not appear to have any parallels in other countries. The UK studies included long distance and urban commuter surveys, but apparently without any significant difference emerging. Miller (1989) also fails to draw attention to long distance versus local travel as a discriminating factor.

A8.11 Trip Time of Day

While the VTTS of the traffic stream will vary with time of day because of vehicle occupancy, travel purpose, degree of congestion and person type, the literature does not yield any evidence that time of day in itself is a significant factor in VTTS (MVA et al. 1987).

A8.12 Conclusions and Recommendations

The finding that VTTS increases with income, but at a less than proportionate rate, appears to be well established. However, as the rate of increase appears relatively small over most of the income range, it may not be necessary to separately identify income groups when applying values of time in practical cases.

Table A8.1 Facsimile of Table 1 from Bradley & Gunn (1991).

TABLE 1: Travellers' Own Values of In-Vehicle Time from SP Analysis

PURPOSE GROUP:	COMMUTING	BUSINESS	OTHER
Sample/Observations:	485 / 5535	469 / 5159	1106 /12166
Base Values by Income (1988 ƒ/hour)			
0 - 1500 ƒ/month	7.0 *	9.1	6.3
1501 - 2500 ƒ/month	7.0 *	9.1	7.4
2501 - 4000 ƒ/month (*base*)	7.7	12.2	7.9
4001 - 6000 ƒ/month	10.3	12.7 *	8.9
6001 - 8000 ƒ/month	10.4	14.5	10.4
8001 ƒ/month or more	12.2	31.4	12.3
Adjustments for Other Factors:			
Household Composition			
1 person/1 worker	+21.7%	+42.5%	+9.0%
2 persons/2 workers	+14.8%	+8.3% *	+7.1%
1 or more children	+20.3%	+4.6% *	+2.0%*
All other types (*base*)	---	---	---
Personal Occupation			
Employed part-time	+29.1%	-17.6%	-4.5%*
House"wife"	---	---	-15.2%
Retired	---	---	-16.5%
All others (*base*)	---	---	---
Age Group			
20 or younger	+43.0%	+45.8%	-12.0%
21 - 35 (*base*)	---	---	---
36 - 50	-14.6%	-6.3% *	-3.1%*
51 or older	-17.3%	-3.4% *	-21.8%
Sex			
Male (*base*)	---	---	---
Female	-20.0%	-0.8% *	+3.5%*
Personal "Free Time"			
64 or more hours/week (*base*)	---	---	---
50 - 63 hours/week	---	---	+5.5%
36 - 49 hours/week	+21.6%	-16.7%	+17.2%
35 or fewer hours/week	+28.0%	-33.1%	+17.2%
Journey (Sub)Purpose			
"Other work"	NA	-19.0%	NA
Education	NA	NA	+19.0%
Shopping/personal business	NA	NA	-9.5%
All others applicable (*base*)	---	---	---
Journey Mode and Conditions			
Car- urban traffic (*base*)	---	---	---
Car- motorway, speed > 110 kph	+9.6% *	+5.0% *	+23.8%
Car- motorway, speed 100-110 kph	+35.4%	+14.5%	-11.6%
Car- motorway, speed 90- 99 kph	+53.0%	+33.4%	-6.8%*
Car, motorway, speed < 90 kph	+67.8%	+33.4%	-6.8%*
Train	+6.1% *	-18.5%	-1.6%*
Bus/tram	-9.1% *	-22.1%	-25.1%
Average Value across the Sample	12.7 ƒ/hour	19.8 ƒ/hour	8.1 ƒ/hour

Notes: --- = no parameter estimated;
* = estimate not significantly different from base group (95% confidence level)

Self-selectivity effects and the different attributes of public transport modes make it difficult to transfer the results of empirical studies involving mode choice to other geographic locations.

The behavioural VTTS for work commuting car drivers is a likely "base value" against which the relative VTTS for other travel contexts can be prescribed as percentage differences, using the Netherlands study as a model. Using the average wage rate as the basis for this value currently leaves a considerable range of uncertainty, between 30% and 70% of the AWR. The value currently recommended in the PEM is nominally 46% (behavioural), but empirical studies based in New Zealand are desirable to confirm or modify this finding.

The correct interpretation of car driver VTTS to arrive at an appropriate resource VTTS for all car occupants is somewhat unclear. Any New Zealand-based study should consider this question in the study design.

Any New Zealand study should also endeavour to compare VTTS for long distance car travel with local urban area travel.

Variations in VTTS with person type which can be ascribed mainly to time scheduling constraints are significant, and these variations should be recognised when prescribing VTTS for evaluation purposes.

A9. EQUITY ISSUES

A9.1 Background

The historic treatment of VTTS in project evaluation in New Zealand up to 1991 was to recognise only a single VTTS in non-working time. This followed the practice in the UK and was justified on two grounds. The first was that evidence from behavioural studies was insufficient to justify differentiating by mode of transport or non-work trip purpose. The second ground was that to carry differences in modal values through to project evaluation would lower the benefits attributed to travel on some modes, in particular urban bus travel, while maintaining or enhancing the benefits attributed to travel on other modes, in particular private car.

Overlaid on this second ground was the concern that, apart from any preferences associated with the quality of service of the transport mode, public transport users as a group have a lower mean income than private transport users, so that any differences in VTTS relating to income could also be implicit in different modal values. The UK DoT took the position that it would be inequitable to recognise such differences in project selection, and adopted what has been called an "equity" value of travel time saving.

The UK DoT-sponsored studies in the 1980s (MVA et al. 1987), and results from empirical studies in Australia and the USA, all greatly increased the information available on modal differences and income effects on VTTS. The UK researchers were sufficiently confident in their results to recommend the adoption of a range of time values differentiated by income group, mode and employment status. However, their results were provided to better inform the DoT on behavioural values of time saving and their brief stopped short of making recommendations on the question of equity values.

Again, the UK DoT opted to apply a single equity value for project evaluation purposes, stating

> *... this policy has had the merit of being even-handed between individuals, regions and modes. ...*

A9.2 Transit New Zealand's Position

As the PEM and its antecedents recognised only a single value for non-work travel time saving, the New Zealand position before 1990 was stated by Cox (1983) to be:

> *... Most researchers have accepted that although the value of time varies with income, and hence schemes which favoured the higher income travellers should be preferred over others, for non-working time a single overall average value (the equity value) of time should be used in assessing alternative schemes. ...*

In December 1990, during the preparation of the PEM, the question of an equity value was put directly to the Transit New Zealand Authority. It was proposed that any variation in the VTTS arising from differences in income should be averaged out for evaluation purposes, but that other preference factors associated with personal time constraints, modal comfort and convenience, etc., could be recognised in VTTS for evaluation purposes. This proposition was accepted by the Transit New Zealand Authority.

A9.3 Discussion

The MVA et al. (1987) research discussed some of the issues relating to equity (although these were strictly outside their brief). The authors pointed out that adjusting behavioural values is an example of the wider question of distribution of project benefits, and whether transport investment is an appropriate tool for social welfare policy. They quote SACTRA (1977):

> *... We consider that this imposition of a single equity value of time for all non-working time savings is inconsistent with the general philosophy of cost-benefit analysis......*

MVA et al. also suggested that at each income level there is a reasonable equilibrium between space and accessibility, i.e. time and land are traded on the housing market (housing location choice/price has been used as a surrogate market for VTTS in some studies). However, trading options may be very constrained for lower income groups.

If an equity value is limited to income effects, then the UK studies indicated that over the scale of lowest to highest income group (a range of over 6:1), VTTS ranged by 1.4:1 for all modes except rail, which showed a range of 2:1. Thus on average there is a 0.075% increase in VTTS for 1% increase in income, although the rate of increase appears to be less than proportionate for higher income levels. However, subsequent studies in the Netherlands showed a much weaker link between VTTS and income. These effects are illustrated in Figure A8.1 in Appendix 8 of this report.

Hensher (1989) notes:

> *... There is a view that for non-working time the behavioural value of time savings should be the same for all modes and trip purposes. The resulting equity value is inconsistent 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. ...*

Waters (1992), in a discussion of the topic, notes the various reasons why governments may opt to recognise, or not, income effects in project evaluation:

- In some cases income effects may be large, such as comparing investments in aviation and roads, and not to recognise these effects leads to an inefficient allocation of resources.
- Benefits are calculated on the basis of increase in net welfare and, while the potential exists for compensation of losers by gainers, this may never occur in practice. Thus recognising income effects would aggravate differences in income distribution, which may be contrary to public policy.
- Governments may respond to popular political pressures to adopt policies which are egalitarian in nature. This is the UK position.

In their review of VTTS for the World Bank, Bates & Glaister (1990) reiterate comments made in MVA et al. (1987) that VTTS estimated empirically represent the money that individuals are willing to pay to save a unit of time for themselves, and that this need not necessarily be the same as the amount a public agency is prepared to pay to save a unit of time for an individual. Bates & Glaister (1990) suggest why differences may occur as follows:

> *... it is proper for public agencies to take into account elements in the valuation which are outside the scope of the individual, or vice versa. Among the elements for which this applies are*
>
> *(a) misperception by the individual,*
>
> *(b) taxation or subsidies such that the cost affecting the individual is not a true resource cost,*
>
> *(c) a difference in the time horizon (for example if individual values are all short run, but transport policy includes long run considerations). ...*

They also observe that, because of strong views held by the various protagonists of different opinions, the controversy is unlikely to be settled for once and for all. In recommending a course of action to the World Bank, the authors noted the practical advantages of using standardised values in all but the most exceptional circumstances. These included minimising the scope for introducing ... *unwarranted distortion to favour particular outcomes* ..., and freeing project rates of return evaluated in different parts of the world from the influences of ... *capricious differences in assumptions....* There is a parallel here for Transit New Zealand which wishes to promote a common basis for project evaluations carried out in various parts of New Zealand.

A9.4 Conclusions and Recommendations

Any departure from WTP VTTS for use in the evaluation of public projects, other than to correct for misperceptions, as described in A9.3 paragraph above, must be regarded as a departure from consumer surplus principles on which social cost benefit analysis of road projects is ostensibly based. In the past, such departures could be rationalised by the rather sparse information on differentiating factors which made anything other than an "average" value difficult to justify. However, this comfortable excuse is no longer valid.

Consequently, if income or any other differentiating factor is to be knowingly ignored, then the reason for doing so should be recognised and agreed on, because the result is potentially to penalise some otherwise "worthy" projects and elevate other less-deserving. It means that objectives other than efficiency are being introduced, implying that one of the basic tenets of cost benefit analysis, namely that there is an optimal distribution of incomes, is not being met and that transport investment is being used as a tool of social policy. It is obvious that no conscious analysis has been made of the effects of applying an "equity" VTTS to the development of transport infrastructure and services.

The ultimate decision is inherently political, so any further investigation of this topic should be to more clearly identify the possible effects in terms of transport project selection between applying WTP values or an "equity" value. As there are practical advantages in reducing the complexity of the analysis if equity values are used, and as there is a limit to the degree of dis-aggregation that can practically be handled, these analysis costs should also be taken into account when recommending a course of action.

A10. VTTS FOR "SLOW" TRANSPORT MODES

A10.1 Introduction

This Appendix 10 reviews the evidence on the valuations of travel time, principally non-work time, for "slow" modes, i.e. walking and cycling. (For any given trip these modes may not actually be the slowest way of making the trip.) The emphasis is on walking and cycling as the main modes of travel, although data on walking as an access mode are also given (as there is a paucity of data on these modes).

A10.2 PEM Valuations

Previous research work for the PEM has devoted relatively little effort to establishing time valuations for "slow" modes. The present PEM value for walking/cycling in non-work time is 60% of the average wage rate (i.e. 1.5 times the value for car drivers). This applies both for walking/cycling as the main mode and for walk/cycle access to the public transport system. Beca (1992) comments that:

> *... The recommended value for walking and waiting time to access transport is 1.5 times the VTTS for car drivers, or 60% of the average wage rate. This corresponds to 2.4 times the in-vehicle value of time savings for bus passengers. The same value is recommended for walking as the main transport mode and also for cyclists, until research is able to provide firm evidence for separately distinguishing these modes. ...*

The PEM value for walking/cycling in work time is $19/h (1991), the same as for car drivers and passengers. This assumption was adopted in the absence of any data for differentiating between walkers/cyclists and car users.

A10.3 Empirical Evidence for Walking

Algers et al. (1985) estimate that time is valued at 74-80% of the wage rate by people who walk all the way to work, while time walking to and from public transport is valued at 55% of the wage rate, and time walking to parking for private transport at 107% of the wage rate.

Miller (1989) notes that most studies value walking time only as a component of trips taken primarily on other modes. The differences between studies are primarily related to the relative accuracy of reporting of walking and in-vehicle time, in surveys reported to support modelling of mode choices. He suggests that Algers et al. (1985) probably found a higher value for travel time from parking than from public transport, because they measured the distance and average travel time from public transport, but had to rely upon estimates by the drivers of their perceived travel time from parking.

Miller finds that the only clear trend from studies on the value of walking time is that the value is higher than passenger in-vehicle travel times (p.15). He concludes that the same value of 60% of the wage rate is the safest to use for the travel time of commuting pedestrians as for drivers (p.16). He assumes that leisure walking trips will have a lower average value as their purpose is simply to have a pleasant walk (p.16).

UK DoT (1987) reported that people valued the time spent walking to and from public transport at about twice that of time spent in vehicles (p.18). It accepted these values as being appropriate for all pedestrian journeys, whether part of a larger journey by public transport or not (p.5).

Cheung et al. (1989) report on SP research (p.236), with results shown below that indicate the VTTS for walking (classified under "public transport") relative to a base time savings value.

	Public Transport Times (Change from base = 100)		
	Business	**Commuting**	**Other**
Walk, for age 16-20	+61.3	-61.6	-47.1
Walk, for age 21-50	+61.3	-61.6	-1.6
Walk, for age 51+	+61.3	+156.0	+165.4

The study by Truong & Hensher (1985) reported in Abelson (1986), shows the following values of travel time savings, including walking time valuations (p.64). The result shows that car drivers and car passengers, in particular, dislike walking.

	VTTS (% of average wage rate)			
	Car driver	**Car passenger**	**Bus passenger**	**Train passenger**
In-vehicle time	50	35	34	22
Waiting time	82	na	96	138
Walking time	126	173	34	79

The MVA et al. (1987) studies did not examine walking as a mode per se, but rather as an adjunct to public transport use. On this basis, the results of the West Yorkshire and Urban Bus Surveys suggest a value which is close to twice the in-vehicle value (p.175).

MVA report that, for the Urban Bus Study (SP-based research), it appeared that time savings for walking time were less highly valued than time losses.

A10.4 Empirical Evidence for Cycling

UK DoT (1987) reports that walking time values are assumed to apply to cyclists where their journey times and convenience are likely to be affected (p.5).

Algers et al. (1985) estimated the value of travel time for commuting cyclists at 56% of the wage rate (p.16).

A10.5 Conclusions and Recommendations

This Appendix 10 is a review of the evidence on VTTS for walking and cycling as main modes in non-work time. It has not covered walking/cycling VTTS for work purposes, nor has it specifically examined VTTS for walking/cycling as an access mode.

A10. VTTS for "Slow" Transport Modes

Most of the limited evidence supports the view that VTTS for walking is generally higher than for in-vehicle time, in either car or bus. On the evidence examined, there seems little case for changing the present PEM assumption valuing walking time at 50% higher than for car drivers, or 60% of the average wage rate. However, this value may be somewhat on the high side, given the self-selecting effect and the health/fitness element in many walking/cycling trips.

For evaluation of most roading schemes, travel time savings (or losses) to pedestrians and cyclists are not usually a substantial component of the total benefits. Partly for this reason, we consider that further research on this issue does not warrant high priority in the context of Transfund New Zealand's research programme.

A11. TRANSFERABILITY OF INTERNATIONAL RESEARCH

A11.1 Introduction

Given that a large body of international research on VTTS now exists, and given the relative paucity of empirical studies in New Zealand, there is and will continue to be a demand for the transfer of international research results for use in New Zealand. In the past this has been done in a rather rudimentary way by accepting:

- The marginal productivity of labour (MPL) approach for work time savings, and carrying out a minimum of investigation of employers' costs and working traveller wage rates and occupations.
- A percentage of the average wage rate (AWR) as the value of non-working time, obtained by converting international research results into percentages of the wage rate in the source country, and then taking some median value of the results of those countries and studies considered to be the most reliable or most relevant in some way to New Zealand.

There are uncertainties both in the way in which research results are transferred and in the way the results have been implemented in New Zealand. While the AWR is a useful basis on which to convert values from international practice, clearly this can only be regarded as a convenience as there is no direct connection between AWR and VTTS.

Despite these difficulties, New Zealand practice will very likely continue to be influenced by international research findings. Some effort should therefore be put into the process for selecting and evaluating international research results, so that those which are not pertinent to New Zealand conditions are excluded, and those that are pertinent are interpreted accurately.

A11.2 Acceptance Criteria for International Studies

As there is now a wealth of international empirical study of VTTS, some criteria are needed for selecting those which can usefully inform New Zealand practice. Possible criteria are:

- Age of the study - theoretical as well as empirical studies suggests that VTTS does not remain stable over time. Also, since research methods in earlier years were somewhat less refined, it is reasonable to impose an age limit. A suggested limit is 1980.
- Transport choice context - some of the international studies have used travel choice contexts which are either unknown or rare in New Zealand. Urban transport in New Zealand cities is more akin to that of provincial towns in Europe. Buses in New Zealand are comparable to urban stage buses in the UK but long distance commuter coaches are almost unknown here.

  Suburban train services in Auckland are not comparable with those in European cities because of their lower speeds and the shorter road distances with less congestion. The Wellington services are more similar to outer London underground (actually above ground) services and suburban rail services in other conurbations.
- Urban density and rural travel distances - which are related to transport options. New Zealand has more in common with the USA and Australia in terms of urban density, vehicle ownership and average traffic speeds. For long distance travel, New Zealand

has less in common with Australia and North America, where inter-urban distances are much greater.

- Transport time and cost budgets - because the opportunity VTTS is influenced by personal activity schedules and time pressures, and also because of the differing costs of goods and services between countries, more relevance should be given to studies from countries of similar character in these respects.

A11.3 Methods of Translating VTTS

The average after-tax wage rate historically has been used as the main means of comparison between VTTS from different studies. This is despite cautions against such practice and determination in technical papers not to express values of time as percentages of wage rate.

Comparing studies across countries by this method risks distortion, for four reasons:

- Confusion between the average income of the working population as a whole, as opposed to the sub-group of the population in the study.
- Incorrect interpretation of variation in VTTS against income effects.
- Where currency conversions are needed, establishment of appropriate exchange rates and indexing for inflation.
- Differences in income tax structures, non-wage benefits to employees, different obligations for employers' cost, and informal economic activity.

A more considered comparison would probably require an understanding of the direct and indirect taxation regimes in the countries concerned when the studies were carried out, the disposition of income on transport versus other household expenditures, travel time budgets, the transport choices that actually exist taking account of accessibility differences and transport cost structures, and the differences in what are ostensibly similar modes of transport. Transfer of VTTS results from international modal choice studies are likely to be particularly difficult because of the social perceptions of each mode, the competing modes that exist, the lengths of trip being undertaken, and the speed, comfort and reliability offered by each mode.

In a review for the World Bank on how VTTS might be more consistently applied to transport project evaluation in developing countries, over a very wide range of social and economic conditions, Bates & Glaister (1990) note:

> *... It is tempting to assume a direct proportionality between income and time values across countries. In their survey of evidence from the developed world, McFarland & Chui (1989) note a marked clustering of average values in the neighbourhood of 70% of the wage. GNP per capita is one of the best documented economic variables across many developing countries (Stern 1989). The range of variation is vast. It seems almost inevitable that the analyst will wish to scale values taken from elsewhere in proportion to relative incomes. Unfortunately the evidence is too thin to support such a simplistic approach with confidence and this is an urgent topic for further research. ...*

A11.4 Recommendations

If a programme of empirical studies of VTTS in New Zealand were to be initiated, probably no great value exists in attempting a more selective review and transfer of international research findings.

However, if a programme of empirical research cannot be funded from New Zealand sources, then such a project may be contemplated. Whether the results would materially improve the degree of confidence in existing or amended values is unclear. Some aspects of the present values probably could be improved, such as the treatment of reliability, but whether international study results can further inform on appropriate "base values" for car and other modes is less certain.

A12. ISSUES IN APPLICATION OF VALUES OF TRAVEL TIME SAVINGS IN TRAVEL DEMAND MODELLING & ECONOMIC EVALUATION

A12.1 Introduction

The Transit New Zealand PEM has its origins in rural road project appraisal. In this context, future traffic demand arises from general economic and population growth, so-called "normal traffic", or occasionally by diversion from other roads. There is seldom reason to anticipate that construction of the road will, in itself, trigger significant new traffic (generated or induced traffic).

The method of application of values of travel time savings in the PEM caters for this assumption, and provides for the evaluation of generated traffic effects by a simple application of the "rule of half", using the prescribed values of time saving and vehicle operating costs. An assumption implicit in this treatment is that behavioural values which influence travel demand and the resource values which are prescribed for evaluation either are the same or that any differences are insignificant or cancel out.

At least two commonly occurring situations in which this guidance is insufficient, are: urban road and public transport networks, particularly where there is congestion; and minor roads which give access to a few identifiable land-use activities, such as farm access roads where the costs of continued maintenance or reinstatement after flood damage is at issue.

A12.2 Restatement of Consumer Surplus Theory

Evaluation of transportation project benefits relies on the microeconomic theory of the consumer, which underlies a whole branch of economics. When dealing with the simple demand for a single commodity, such as the number of trips made on a single transport mode between one origin and one destination, then the theory is relatively easy to apply. In more complex situations its method of application has also appeared comparatively straightforward, but has come under scrutiny and challenge in recent technical literature.

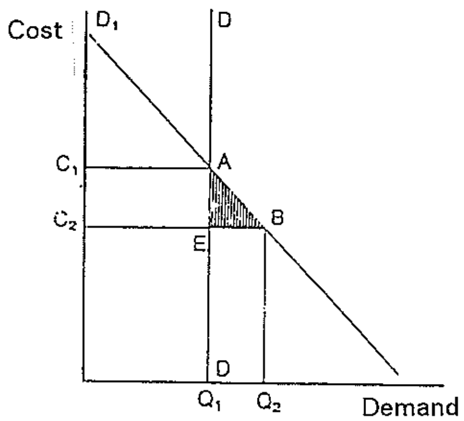
As an example of the simplest expression of this theory, consider how an individual person's demand for a commodity varies with the cost of supply (Figure A12.1):

- The amount purchased can be plotted against user cost, giving the familiar demand curve.
- At user cost (C_1) the individual consumes an amount of commodity (Q_1). If the cost is reduced to C_2, the amount consumed rises to Q_2.
- The savings to the individual are an amount $Q_1(C_1 - C_2)$ on the original quantity, Q_1, plus an amount represented by the area of the shaded curvilinear triangle *ABE*.
- If the demand curve is assumed to be a straight line over the range between C_1 and C_2, then this additional amount of saving is equal to $(Q_2 - Q_1)(C_1 - C_2)/2$.
- On addition these two expressions can be reduced to $(Q_1 + Q_2)(C_1 - C_2)/2$, i.e. the average consumption times the change in user cost.

Another way of looking at this theory is that the gross value to the consumer is the cost (C_1) at which he/she would just be willing to make the purchase:

- If the actual cost is reduced to C_2, the difference $(C_1 - C_2)$ is a net value of the commodity's worth to the consumer (expressed through WTP) once the cost of supply (C_2) has been subtracted, i.e. the consumer surplus.
- If the commodity is travel, then the first expression is the road user savings to existing (normal) traffic and the second term is the savings to new (generated) traffic.

Figure A12.1 Demand for commodities in relation to cost of supply.
Source: Mackie & Bonsall (1989)



Travellers will respond to market prices or to their perception of them. So it is appropriate to use costs that explain behaviour when modelling transport demand. These are the so-called *behavioural costs*, and are the costs that find their way into generalised cost functions for trip distribution, modal split and route assignment.

Social costs (u) are those that reflect the traveller's WTP to save time, distance or to reduce accident risk. Clear-cut choice situations are required conforming to Harrison's nine criteria (Harrison 1974), either in the field to give revealed preference measures of WTP, or as SP experiments in more controlled but less realistic situations. One reason why social costs can vary from behavioural costs is because of constrained choice. The interpretation of behavioural costs as social costs (possibly resulting from calibration of a demand model to replicate observed behaviour) should be regarded with caution if the necessary experimental conditions do not apply. Social costs are frequently referred to as behavioural costs, thus blurring the differences which may exist.

When evaluating transport investments from a national economic viewpoint, government agencies generally require the use of *resource costs (r)*. Resource costs are net of transfer payments such as taxes, duties and subsidies, and reflect the cost to the nation of the consumption of transport.

Perceived costs is a term frequently used to describe the way individuals perceive (unconsciously) the costs they incur, and these may differ from the real objectively measurable cost. Thus it is commonly believed that drivers' perceived cost of running a car is limited to its fuel cost (whether this belief is correct or not is not discussed here). Perceived costs are normally equated with those that affect demand behaviour, so perceived and behavioural costs are generally interchangeable.

Reported costs can also be mentioned for completeness, although they are not relevant to the following discussion. Reported costs are those indicated from a respondent's answers to questions about his/her behaviour and may not match with objectively measured costs. Reporting bias arises from various causes including post-choice rationalisation of behaviour. It can complicate survey measurement.

If we define social costs as $u1$ and $u2$, and resource costs as $r1$ and $r2$, and the transport demand (which will have been modelled from behavioural costs) as $q1$ and $q2$, then the net benefit is:

$$B = (q2 - q1)(u1 + u2)/2 - q1(r1 - r2)$$

(gross value to consumer) – (resource cost of supply)

This can be expressed in another form:

$$B = (q1 + q2)(u1 - u2)/2 + q2(u2 - r2) - q1(u1 - r1)$$

This means that for evaluation in a general case, where there is a change in transport demand, both the social costs and the resource costs need to be known.

The current stated practice in the PEM is to use resource costs throughout. This is correct in terms of the above theory if resource and social costs coincide, when the above expression reduces to:

$$B = (q1 + q2)(r1 - r2)/2$$

Also, if there is no change in transport demand $(q2 = q1)$, then the expression reduces to:

$$B = q1(r2 - r1)$$

Again, only the resource cost needs to be known.

The three components of road user savings which currently feature as tangible items in the evaluation are time, vehicle operating costs and accident costs.

12.3 Differences between Social Costs and Resource Costs

For non-work time savings, social costs are derived from preference studies designed specifically to yield trade-offs between cost and time saved. The social values of travel time saving are based on objective measures of time duration, not perceived measures, so actual time savings are used in evaluation. WTP is accepted as the basis of economic evaluation, but because of direct and indirect tax effects it may be necessary to adjust the social values to arrive at resource costs. At present, token acknowledgment of this is made in the PEM procedures (see Appendix 3 of this report on taxation treatment).

For work time savings, the resource costs are not based on WTP studies but on MPL. The case for making no correction to allow for differences in social and resource costs only holds if WTP response corresponds to the determined resource value. The empirical evidence is rather thin but tends to support this contention.

For vehicle operating costs, social and resource costs are generally believed to differ, as drivers are thought to respond to only a part of the mileage-based costs of vehicle operation, possibly just fuel costs. However there seems to be a shortage of recent studies to confirm this assumption. In this case, the PEM would appear to fall short in not including perceived costs as well as resource costs. In practice, because of the large amount of taxation on the use-related component of vehicle operating costs, the perceived cost (say the market cost of fuel) may not differ greatly from the resource cost (tax-free cost of fuel plus other operating costs such as tyres, repairs, etc.). However this is not clearly established.

For accident costs, WTP to reduce accident risk is now accepted as a basis for resource costs, although corrections for misperception, such as indirect tax effects, may still be required. It is believed that WTP respondents do not include the material clean-up costs of accidents in their valuations. So the resource costs of accident attendance and the medical system are additive to the adjusted WTP cost for economic evaluation. In passing it may be noted that accident risk avoidance does not normally appear as a choice variable in behavioural models of travel demand.

A12.4 Roads to Isolated Land-Use Activities - Application of Producer Surplus Methodology

In most cases, roads have an established traffic which arises from a large number of land-use activities. It is impractical and unnecessary to investigate the effect of a road improvement on each land use. Instead travel demand is estimated in a more general way from population and economic growth indicators, or from general expectations for land development, and by applying trip production relationships such as category analysis of household travel demand, or regression equations for trip productions and attractions of land uses.

For new "developmental" roads, and for roads on which there are only a few users, this method of demand estimation tends to break down. Such roads are also at the margin between being considered as a public road or as a private road (in the latter case the users could be expected to contribute at least in part to road development and maintenance).

For such roads the methods of road user surplus, measured as time value and vehicle operating cost savings, also tends to break down because generalised values are less likely to be appropriate and the individual circumstances of the road users can more readily be investigated. Also, when questions of keeping a road open or closing it arise, the shape of the demand curve cannot be readily approximated by the "rule of a half".

Appropriate methods of dealing with this type of road involve a consideration in some detail of the relationships between transport cost, time and quality on the individual land-use activities. The study should consider the extent to which transport cost savings are passed on to the land-use enterprises, how these savings will stimulate new production, and the resulting producer surplus and transport user surplus (where producers and transport users differ).

A12.5 Urban Roads and Network Analysis

While benefits of rural road improvements are reasonably evenly shared among time saving, vehicle operating cost saving and accident reduction, benefit estimates for urban roads are frequently dominated by travel time savings (typically 80% of benefits). It is therefore of great importance that the valuation of time savings be correctly based.

Applications of cost benefit analysis to traffic networks has usually (such as in the UK COBA) assumed fixed travel matrices, i.e. the trip ends are assumed to be fixed and the trip distribution is assumed to be fixed. In such cases only in the assignment process is there scope for variation in routes as a result of the project. The change in user benefit on a network in such situations can be simply calculated by summing the resource costs of vehicle operation, travel time and accidents on a link-by-link basis, aggregating for the whole network and comparing against the "Do Minimum" option.

The assumption that travel demand will be unaffected by improvements to urban roads, while convenient, is not very realistic, particularly if the existing network is experiencing congestion. If travel demand is assumed to be variable, either by allowing redistribution of trips or changes in the number of trips, then the evaluation process becomes somewhat more complex.

In the UK, the DoT view is that such effects are small:

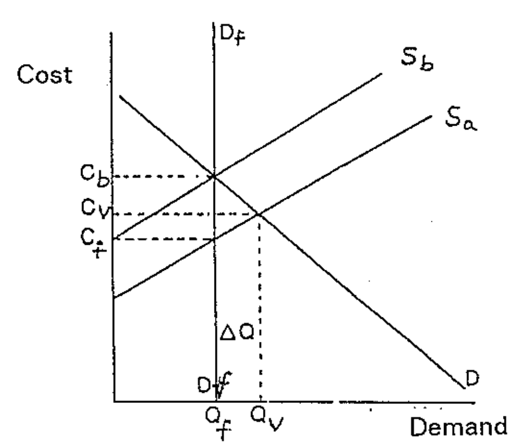
> *... In most cases, the variable trip evaluation of benefits is unlikely to yield more than about 10% extra benefits over the fixed trip evaluation, although this will be scheme-specific ... (UK COBA 9).*

While this observation is probably correct in urban areas where traffic is generally free-flowing, the situation may not be so simple where congested networks are being appraised.

A12.6 Fixed versus Variable Demand and Congested Networks

The following discussion is derived from Mackie and Bonsall (1989). Figure A12.2 is used to illustrate the effect of assuming a fixed trip matrix in cases where there is congestion.
- The demand curve for fixed demand is a vertical line *Df* and variable demand is shown as *D*.
- The supply *(S)* versus cost *(C)* curves are shown as S_b and S_a for before and after.
- In the before situation, point *b* is the intersection of the supply and demand curves, with demand Q_b and cost C_b.
- After the project, a fixed demand assumption would indicate cost C_f and demand Q_f, while a variable demand would indicate cost C_v and demand Q_v.
- The variable demand C_v is greater than C_f but less than C_b.

Figure A12.2 Demand-cost relationship assuming a fixed trip matrix where there is congestion. Source: Mackie and Bonsall (1989)



In the *fixed demand* case the project benefits are:

$$\begin{aligned} b_f &= 0 \text{ (no change in gross worth of travel)} \\ &= Q_f\,(C_f - C_b) \text{ (change in travel cost)} \\ &= Q_f\,(C_b - C_f) \\ &= Q_f (Q_v - Q_f)\,(D + S) \end{aligned}$$

In the *variable demand* case, the project benefits are:

$$\begin{aligned} b_v &= (Q_v - Q_f)\,(C_v + C_b)/2 \text{ (change in gross worth of travel)} \\ &= (Q_v \,.\, C_v - Q_f \,.\, C_b) \text{ (change in travel cost)} \\ &= (Q_v + Q_f)\,(C_b - C_v)/2 \\ &= (Q_v + Q_f)\,D\,(Q_v - Q_f)/2 \end{aligned}$$

In Figure A12.2 it is not clear whether the benefits measured under fixed demand are greater or less than those under variable demand. If the slopes of the demand and cost curve are included, the two are equal when:

$$S = D\,(Q_v - Q_f) \,/\, (2 \,.\, Q_f)$$

Note that, if demand is perfectly elastic, at $\delta D = 0$ any additional road supply is immediately taken by new demand from suppressed traffic and the economic benefit is zero.

If a conservative approach to benefit estimation is taken, then if the benefits under a fixed travel demand assumption are to be lower than those calculated from variable demand:

$$S < D/2\,(Q_v - Q_f) \,/\, Q_f$$

or

$$S < D/2\,(Q_v / Q_f - 1)$$

This condition is more likely to hold where the change in demand is large (as a proportion of the "before" project demand), and where the rate of increase in travel cost with travel volume is low (as for less congested networks), i.e. it is a relatively elastic supply. Conversely, a fixed demand assumption is more likely to lead to an over-estimate of benefit for small changes in demand and where user cost rises more steeply as travel volume increases (more congested networks).

The implication is, then, that to ignore demand response, when evaluating road user benefits from small changes to a congested network, could well lead to an over-estimate of benefits.

A12.7 Interpretation of Transport Modelling Results

With the cautions noted above regarding the assumption of fixed demand in urban networks, to take advantage of the demand responsive features of traffic network models in economic evaluation may seem reasonable. It is common practice in New Zealand to include the re-distribution of trips arising from increased network accessibility in the economic evaluation procedure. This then requires the inclusion of both behavioural and resource costs in the economic evaluation as noted in A12.2 of this Appendix.

In the technical literature it has been frequently demonstrated that the confidence that can be put in economic evaluation using modelling outputs increases as the specification and the level of disaggregation of the model improves. (Current approaches to modelling consumer choice are generally based on compensatory random utility maximising models.) Also important is that travel models should incorporate the possible dimensions of traveller response and should not be constrained. Traveller response to increased urban road network capacity can involve:

- trip rescheduling and contraction of the period of peak traffic volume
- diversion to lower cost routes
- change of mode, away from public transport
- spreading of trip destinations
- new trips, trip generation
- increased car ownership
- change in land use.

The complexity of responses and the changing time scale of response is not easily handled and transport models are generally constrained in one way or another.

For the older generation of strategic network models, the numbers of trips are usually related to land use and planning variables, which in turn were forecast without reference to the transport network. The feedback of accessibility into trip generation was ignored. (A series of relatively simple demand models were developed in New Zealand in the 1970s for smaller centres that did allow for changing zonal trip generation with changing interzonal travel cost. The larger metropolitan models with a more complex structure and larger survey base did not allow for this.)

The metropolitan models included modal split stages, although with the declining size and influence of public transport on road conditions, the tendency in recent years has been to divorce public transport planning from private vehicle trip modelling.

Car ownership forecasts have generally been made at a national or regional level, relying on Tanner models of saturation but without reference to network loading in the local area. The effects of road conditions and costs on car ownership has not received much study.

Attention has been drawn in the literature to anomalies that can result when interpreting the output of aggregate models in congested urban situations and where there are unrealistic constraints in the model.

The extent to which coefficients against time and distance in generalised cost formulations for trip distribution and assignment models can be interpreted as "behavioural" values is open to question. For aggregate-staged models in common use in New Zealand these coefficients are often set at the market cost per km of fuel as the coefficient against distance, and the PEM time values used as the coefficient against time. An exponential function including the generalised cost and two other calibration constants is then used to fit the observed trip length/frequency distribution as closely as possible for each trip purpose. Apart from considering whether the selected behavioural values are appropriate, the exclusion of other choice variables and the aggregate nature of the model makes the interpretation of the resulting re-distribution or re-assignment of trips as an accurate measure of behavioural response somewhat uncertain.

A13. FUTURE TRENDS IN TIME VALUES

A13.1 Introduction

Existing practice by Transit New Zealand has been to increment the VTTS from year to year using the average wage rate (AWR) as the basis for this forward indexing. While this process can be justified for the marginal value of working travel time, it is not clear that this is also applicable to non-working time.

The PEM makes no allowance for future changes in VTTS over time, although it is now fairly clear from past experience that long-term changes do occur, and that the factors influencing change can, to some extent, be forecast. In the UK, the COBA Manual (UK DoT 1989) allows for VTTS to grow with GDP per capita and provides low and high GDP growth assumptions on which to base VTTS for evaluation of projects over a long-term time horizon.

A13.2 International Study Findings

The UK study (MVA et al. 1987) provides a convincing argument that VTTS for non-work time cannot be assumed to remain at a constant percentage of the AWR over time, because of changes to the marginal utility of income which could conceivably arise in time, and because of changes in money constraints, such as from the development of new technologies.

Studies in the 1960s indicated that non-work VTTS were of the order of 25% of the AWR, whereas studies in the 1980s seldom produce such low findings. It seems unlikely that all such differences can be attributed to study methodology, but more likely that a rise in the value of non-work time in relation to the average wage has taken place over this period.

MVA et al. (1987) set out various ways in which non-work VTTS may change in future, assuming a *"... general scenario of economic growth and expansion ..."*, as follows:

- Reductions in working hours, lead to a reduction in VTTS
- Reductions in unemployment, lead to an increase in VTTS
- Increases in proportion of retire persons, lead to a reduction in VTTS
- Improvements in quality of travel, lead to a reduction in VTTS
- Enrichment of leisure time activities, causes an increase in VTTS
- Increase in the attractiveness of work, causes an increase in VTTS
- Increase in female participation in the workforce, causes an increase in VTTS.

While the direction of these effects may be argued, the conclusion remains valid that in total the aggregate effects cannot be assumed to be neutral. In the recent context of New Zealand economic and social change, the second item should arguably be reversed and it is debatable whether the fifth and sixth are in the direction indicated. It may in fact be the case that the weight of change through the 1980s has been towards a lower VTTS while, before that time, economic and social changes would have been leading to increased values.

A13.3 Implications for Practice

If indexing on the basis of wage rate is an imperfect mechanism, the next question is whether a more satisfactory and practical method can be suggested. This would evidently be based on monitoring the changes noted above.

Working hours, employment, the proportion of retired persons and female participation rates are statistics which are routinely gathered by the NZ Department of Statistics. The other aspects are more difficult to monitor and could probably be regarded as neutral, at least over the medium term.

Evidence of the variation in VTTS between full-time employed, part-time employed and not formally employed persons, and also the differences by age and family grouping, form a basis for differentiating these aspects which could conceivably be incorporated into the evaluation process through surveys of the travelling public. This leaves working hours per year and the utility to the employee of payment for full-time work as factors which would be used to modify the non-work VTTS for full-time working adults.

A13.4 Recommendations

- The theoretical basis and practical implementation of an improved method for annual indexing of the non-work VTTS could form an individual item of research or be included with research into the treatment of taxation and establishing the marginal cost of labour for work time savings.

- Such research should also consider long-term forecasts of change in socio-economic characteristics of the population, and how these should be incorporated into project evaluation.

- The output of such research would allow the PEM to include sensitivity of project cost benefit analysis to future economic growth, in a similar way to the UK practice.

A14. TREATMENT OF SPEED LIMITS IN EVALUATING TRAVEL TIME SAVINGS

A14.1 Introduction

This appendix discusses the issue of how travel time benefits associated with exceeding the posted speed limit on a particular road should be treated in evaluation terms. This is a significant issue, particularly in many urban situations where average speeds above the 50 km/h speed limit are often recorded.

The first section describes the present approach adopted in the PEM and the rationale/arguments behind this approach. The next section reviews the limited international research literature on the topic. International practice is then described. The last section draws conclusions and makes recommendations.

A14.2 Present PEM Approach And Rationale

PEM states (S3.4.2) that:

> *... As a matter of policy, travel time savings arising from travel speeds above the posted speed limit are not to be considered as a benefit for any improvement project.*
>
> *If the projected average speed exceeds the speed limit, travel time savings shall be computed assuming that all vehicles travel at the posted limit. Vehicle operating costs should be computed using the actual speeds for the site....*

This is a continuation of the previous NRB policy. The issue was originally discussed in the RRU (Road Resarch Unit) Economics Sub-Committee, the Administration Committee and referred to the NRB for a decision, where the policy was confirmed. During the preparation of the PEM, this matter was raised again and the opinion of MOT Land Transport Division was sought. Again, it was held that a public policy procedure should not be seen to condone infringement of a legal requirement.

The logic behind the policy is that the speed limit is an expression of society's value in preventing the risk and fear of accidents. As an acknowledgment that limits are set with the expectation that a proportion of drivers will exceed them, the policy is applied to the average speed of vehicles. However this rather vague qualification introduces considerably scope for inconsistency. The more that a project is divided into smaller sections (with mid-block speeds distinguished from slow-downs and stops), the speeds of different classes of vehicle and the distribution of speeds within the classes considered, the more likely it is that some vehicles will be found to be exceeding the limit. The policy is thus difficult to apply in practice.

The urban speed limit of 50 km/h has been in general use for many years. While 50 km/h or lower is appropriate on local roads, it is also imposed on many urban arterial routes on which the speed of the traffic stream is often 60 to 65 km/h, with very few vehicles travelling below the limit. While situations will obviously vary, these speeds are often not excessive with regard to road conditions and the braking and manoeuvring capabilities of vehicles. When traffic congestion brings speeds down to 50 km/h, this is often regarded as unsatisfactory and perceived as a traffic "problem" requiring additional road capacity. However, the time savings from "solving the problem", by reducing link delay, cannot be claimed as a benefit under the current procedures.

Instead of relying on the posted speed limit as a proxy for avoiding accident costs, it would be preferable to quantify the actual risk of more or less accidents occurring as a result of the improvement being proposed. However, if this approach is taken, then time savings should logically be offset against increased accident costs. As the PEM presently stands, only the vehicle operating costs and the accident costs of increasing speeds are recognised and not the travel time benefits.

A14.3 International Literature

Bruzelius (1979) suggests that there are two types of time allocation constraints, both of which are linear. In the first, the time requirements are assumed to be exogenously given to the consumer, i.e. a road speed limit will restrict the consumer to driving times below a certain threshold. In the second time constraint, the time requirement is endogenous where the constraint is relevant to car journeys where the driver is free to choose any speed (p.31).

Bruzelius notes that estimates of values of time obtained from observing choice of speed for a car journey cannot be used unless it can be ascertained that the driver chooses his speed to minimise the total costs of time and money. It needs to be assumed that the driver does perceive that his cost per kilometre is dependent on speed, and that the driver does not go fast because driving fast is valued highly per se. For example, drivers may prefer to travel at high speed even though they are not willing to pay at all to save time.

Miller (1989) suggests that the choice of speed primarily involves a trade-off between time, safety, operating cost, and, if the choice of speeds is constrained by the speed limit rather than differences in road conditions, the potential cost, time loss, and inconvenience associated with a speeding ticket.

A14.4 International Practice

In the **United Kingdom**, current practice is described in the COBA 9 Manual (UK DoT 1989). The Manual itself does not make clear whether there is any general policy that evaluation speeds (on any link) should not exceed the posted speed limit. For instance:

S5.1.3: *... In most cases the limiting speed should be the legal speed limit....*

S5.3.11: Notes that rural speed relationships may be applied to roads through small settlements, despite possibly lower speed limits.

However, we understand from discussions that the practical application of COBA 9 is such that maximum link speeds would be limited to the posted speed limit. This limit is one input parameter in link specification, and then the maximum speed calculated is limited by it. In the COBA 10 version, the maximum link speed for modelling/evaluation purposes is always cited as the speed limit, even though the speed/flow curves might indicate speeds above this limit.

To our knowledge, there has not been any philosophical debate on this topic in the UK or any explicit ruling by the UK DoT.

In **New South Wales**, this issue has also not been the subject of any significant debate, nor has it (to our knowledge) become an issue in other Australian States or at the Federal level. The NSW Roads and Traffic Authority (RTA) Economic Analysis Manual (1990) makes no reference to the point.

RTA's current modelling techniques for urban areas apply speed/flow curves without any cut-off values at the speed limits. As a result, evaluations may indicate speeds and corresponding benefits above the posted speed limit. The RTA (informal) view appears to be that a cut-off at the speed limit should be applied and that any benefits from higher speeds should not be counted. It also appears in such circumstances that the RTA view is that accident costs should be assessed at a level consistent with the speed limit. However, such evaluations have raised questions as to whether present urban speed limits (e.g. 60 km/h) should be raised in specific circumstances.

In **British Columbia**, the roading evaluation manual specifies the following maximum speeds for evaluation purposes relating to speed limits of 80 km/h or lower (Waters 1991) as follows:

Speed Limit (km/h)	Max. Evaluation Speed (km/h)
80	87
70	78
60	70
50	60

Thus, while the speed limit had an influence on the maximum speeds appropriate for evaluation, it is not used as an absolute limit in the way that is done in PEM.

A14.5 Conclusions and Recommendations

The present PEM requires that average speeds on a road section should be restricted to no more than the speed limit for evaluation purposes, whereas vehicle operating costs and accident costs are to be calculated based on "unrestricted" speeds. This has major implications for some project evaluations, particularly on higher standard outer urban roads with 50 km/h limits. There are also significant practical problems in applying the restriction consistently in the evaluation procedures.

We would have some sympathy with the MOT view that:

> ... *The Ministry would not support a situation where the Authority is in effect approving projects which include asserted benefits to road users from exceeding the posted speed limit....* (MOT letter to Transit New Zealand, 21.3.91).

Internationally, different road authorities adopt rather different practices, although we have not identified any country where the issue has been one of major debate:

- In UK, COBA effectively restricts speeds on any link to the posted speed limit. These limiting speeds are then applied in evaluating VOC and accident costs as well as travel times.
- In NSW, the RTA Economic Analysis Manual does not incorporate any procedures to restrict speeds to the speed limit, although the RTA (informal) view is that benefits from

exceeding the speed limit should not be counted in evaluation. However, these situations have led to review of speed limits on certain urban route sections.

- In British Columbia, the Economic Analysis Guidebook explicitly allows speeds above the posted speed limit.

Noting the MOT view and international practices, we suggest that one of two positions should be adopted for evaluation purposes:

- All benefit components should be based on average speeds on any link not exceeding the posted speed limit. (This is the approach adopted in UK.) We recognise there may be some practical difficulties in applying this, and that its application may not be fully consistent (e.g. because of differences between average link speeds and maximum speeds).
- All user benefit components should be based on "unrestrained" speeds, as modelled (i.e. ignoring the speed limit).

We consider that the present PEM procedure is an illogical hybrid between these two positions, in that it denies the travel time savings of higher speeds but counts the additional VOC and accident costs.

In situations where surveys on existing roads (or model estimates for upgraded roads) indicate that the average traffic speed significantly exceeds the speed limit, there may well be a case for reviewing this limit. It is clear in such situations that the existing limit is not being respected, so it may well be preferable either to increase the limit, or to take measures to better enforce it. The PEM cost functions (for time, VOC and accidents) could be a helpful input to such reviews.

This case for selective review of speed limits appears to be generally supported by MOT:

> ... *The Ministry is prepared to review posted speed limits, on a case by case basis, to determine if they are appropriate to the specific circumstances involved...*
> (MOT letter to Transit New Zealand, 21.3.92).

Also the Transport Minister has stated that the Government is considering introducing new speed limits of 60 km/h and 80 km/h for some roads, and that a working group was being set up to consider the issue (Evening Post, Wellington, 2 Nov. 1992).

A15. REQUIREMENTS FOR REPRESENTATIVE TRAVEL DATA

A15.1 Introduction

Should a matrix of time values or, more likely, a base value with modifying additive or multiplicative factors eventually be recommended, the practical process of applying such a system in the evaluation framework needs to be considered. The process requires that characteristics used to differentiate VTTS among travellers should be either capable of ready identification and measurement in the field, or else that special surveys be undertaken to provide "standard" data over the range of transport situations likely to be encountered in practice.

A15.2 Data Requirements

The range of data requirements comprises:

- Typical mix of travel purposes for drivers and passengers by age/sex/employment status of person, type of vehicle, time of day, and type and location of road or public transport mode.
- For each of the above travel purposes, the mix of occupational categories in a form which can be related to NZ Statistics Department data on employment and wages.

Information of this kind is available only through roadside observation and questionnaire surveys. Ideally, it would be useful to obtain correlation between the less readily observable traveller characteristics and features which can be observed without the need to stop traffic (for example the number of vehicle occupants and sex/age mixtures).

A15.3 Previous Investigations

Previous attempts have been made to collect data of this nature. The first is described in NRB Road Research Bulletin No. 17, *Vehicle Occupancy, Trip Purpose, Traffic Composition and Vehicle Operating Speeds* by P-E Consulting et al. (1973),which was a pilot roadside survey at three State Highway locations. For reasons which are now difficult to determine, this project did not proceed beyond the pilot stage. This study also included vehicle speeds, which formed a prominent part of the survey.

In 1986, during the preparation of NRB TR9 (Bone 1986), an effort was made to collate traffic survey data undertaken for other purposes, and this collection formed the basis of the standard traffic mix tables in its Appendix A4 to that technical recommendation. Following this the Administration Committee of the NRB Road Research Unit initiated Project AD/46 *Traffic Data for Economic Appraisal,* which attempted a larger collation of traffic survey data by canvassing local authorities and traffic engineering consultants around New Zealand. The accumulated data were put into spreadsheet format but efforts to reduce this to a concise and consistent form were not very successful. In 1990/91 the data were reviewed and added to by the Traffic and Safety Section of Transit New Zealand, resulting in Appendix A4 to the PEM.

Information on trip purpose is, in fact, seldom surveyed outside urban transport studies. While the recent studies in Auckland, Wellington, Christchurch and Dunedin should provide more information for these main centres, representative trip purpose data for provincial centres and rural traffic will still be in short supply. There is a general shortage of information on weekend travel and the composition of traffic during holiday peaks on rural highways which carry recreational traffic. Vehicle occupancy data are also in short supply, particularly on rural highways, and the occupancy data are seldom linked to trip purpose. There is also ambiguity concerning child occupants and whether or not they are included in the standard traffic mixes in the PEM Appendix A4 tables of typical traffic mixes, and in the application of a nominal 1/3 of the adult VTTS.

A national survey of driver exposure has been carried out by the NZ MOT. It is possible that results from this survey could assist in obtaining representative travel data, but this requires further inquiry.

A15.4 Need for Agreement on Classification

A reappraisal may be required of an appropriate "typical" road classification for discriminating trip purpose, vehicle occupancy, type of traveller and time of day for the purposes of economic evaluation. Appendix A4 of the PEM provides for Urban Arterial, Urban Industrial, Urban Other, Rural Strategic and Rural Other roads. However this classification is not ideal. It is partly conditioned by the availability of data (for example there is no disaggregation into time periods except for urban arterial roads), and other classes of road have been suggested (e.g. suburban arterial, urban motorway, rural recreational). Any revised road classification for economic evaluation purposes should ideally be compatible with road classification for traffic design and transport planning purposes.

Agreement will also be required on an appropriate characterisation of work (business) purpose travellers. At present the New Zealand Standard Occupational Classification is used but this does not identify those conditions of employment which determine what proportion of time spent in work-purpose travel is remunerated by the employer, what percentage of the time is transferred to work and to leisure, and what proportion of travel time is used for work activity and how productively. A classification built around these criteria would be more appropriate.

A15.5 Recommendations

Past efforts directed towards obtaining representative travel data for economic evaluation purposes have been fragmentary and have a weak statistical base. However, reliable information on this topic is as important as reliable valuation of unit time savings. Because those undertaking project evaluation will, in most cases, not undertake their own surveys of travel purpose, a range of typical values is needed which adequately covers the range of road types and traffic composition likely to be encountered.

Unlike some other aspects of VTTS, travel data for applying time values can only be obtained through investigation in New Zealand. Obtaining such data should therefore be given a high priority. Such a project should first commence with a review of what is recently or imminently available from urban transport studies, and from the MOT Driver Exposure Survey. It should be co-ordinated with a research project into time transferring behaviour of business travellers. This latter project should precede it. Previous consideration by the former NRB Road Research Unit indicates that this project is likely to be relatively high cost, because of the large survey effort required. An outline specification for the proposed research project is given in Section 4.3.5 of this report.

A16. EVIDENCE FROM URBAN TRANSPORT STUDIES IN NEW ZEALAND

A16.1 Introduction

Several recent and current urban transportation studies in New Zealand have involved extensive surveys of travel patterns and the development and calibration of disaggregate travel choice models. These surveys/models potentially provide one of the few sources of travel time values in New Zealand. These are behavioural values, disaggregated by mode and trip purpose. This Appendix 16 comments on the values derived or derivable from recent and current transportation studies in Wellington, Auckland, Christchurch and Dunedin.

A16.2 Wellington Studies

The greater Wellington Land Use and Transport Strategic Review (GATS) undertaken by the Wellington Regional Council (WRC) involved household interview and other surveys and the development/ calibration of a disaggregate generation/ distribution/ mode split model. Behavioural values of time were derived in the model calibration process by:

- Mode – car driver; car passenger; public transport (in-vehicle, walk, wait-time), "slow" modes.
- Purpose – home-based work, home-based employer's business, home-based education, shopping social/recreational, non-home based employer's business, non-home based other.

Although values have been derived for this mode/purpose matrix, the values produced so far are implausible in a number of respects and WRC is carrying out further model calibration work. While a more consistent set of values may well result, it seems likely that they will have a considerable margin of uncertainty associated with them, and should be regarded as indicative at best.

A16.3 Auckland Studies

In the current Auckland Transport Models (ATM) project, Auckland Regional Council (ARC) has derived VTTS estimates from both RP and SP sources:

- The RP values have been derived from model calibration, based on data principally from its Home Interview Survey and On-Board Public Transport Survey.
- The SP values have been derived from SP surveys of modal attributes and preferences.

The VTTS values from these two sources are reported in the ATM technical report.

A16.4 Dunedin Studies

The Dunedin Transportation Study involved a Home Interview Survey (HIS) covering trips by all modes, but the main model does not include a mode split component and public transport travel has been dealt with separately. A disaggregate modelling approach to person trip generation and modal split is understood to have been considered (using the Wellington GATS study as a basis). However, in order to expedite the study, the model developers reverted to a traditional model form based on category analysis and land use variables on a zonal basis. Thus while a multi-modal logit model could potentially be constructed and calibrated on the HIS data, this has not been done (and substantial work would be involved).

No useful VTTS information is therefore currently available from the Dunedin studies.

A16.5 Christchurch Studies

The approach adopted is similar to that in Dunedin, and thus no useful outputs on VTTS could be obtained without considerable further work.

A16.6 Conclusions

To date, only limited evidence has been obtained from the recent round of urban transport studies in New Zealand, that would be helpful in improving the VTTS figures in the PEM. This is principally from the Auckland ATM project and comprises behavioural values from both RP and SP surveys. Further evidence may result from recalibration of the Wellington GATS model.

The evidence that is available is likely to be more helpful in relation to VTTS for the various components of public transport trips, rather than for car travel by different purposes.

A17. THEORETICAL BASIS OF THE VALUE OF TRAVEL TIME

A17.1 Conceptual Issues

It is important to have a clear understanding of what is meant by "resources consumed" in the process of "consuming" travel time. It needs to be recognised that much of the process of consumption is actually a transfer of time from one activity to another and as such is not "time saved" per se. Hensher & Truong (1985) prefer the term "value of transferring time" rather than "value of travel time savings" to underline this point.

The amount of time spent on an activity is an outcome of a utility maximisation problem subject to monetary and resource constraints as well as to technological and institutional constraints. Examples of the technological constraints are the available set of modes which put 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.

Economists sometimes 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 is an unambiguously valid position for estimating national income aggregates, it is an incorrect principle for social cost benefit evaluation. The cost to the community of a resource to be used in a project is determined by the *value* it creates in the use from which it is to be moved. 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.

For example, if a resource is moved from the production of some good subject to a 100% tax, its cost to the project must be valued as equal to the price, which is not equal to but twice the resource cost. This distinction between "cost" and "value" is fundamental to an appreciation of this argument. The correct economic concept is "opportunity cost" to the community (or nation) of an adjustment in travel time. The answer is dependent on the worth or value of a resource in an alternative use.

The distinction between a resource for an individual, for a firm, and for the nation as a whole is critical in understanding what we are trying to value when we talk of the resource value of time. In a social cost benefit analysis with an emphasis on efficiency measures, we are evaluating travel time savings from a national or community perspective, in terms of what it is worth to the community if it were transferred to some other activity rather than in terms of what value an individual or a firm places on a resource.

Since we tend to assume (implicitly) that our resources already exist in that they are being utilised elsewhere, then market price is the appropriate basis of identifying the opportunity cost of a resource, i.e. its value to society. The theoretical model assumes a perfectly competitive market, whereas in reality 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 resulting from 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 through market prices, those resources may actually be worth less in a competitive market. That is, institutional constraints have artificially overpriced the real value of a resource.

The resource value of travel time "savings" is defined as the amount of money society is willing to pay for a unit saving in travel time, holding constant the income distribution and utility. Alternatively it represents the worth to society of transferring time to another use.

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, for example work or leisure (non-work), we should recognise that a lot of time saved in travel involves a mixture of trade-offs, leisure-travel and work-travel. For example, an individual travelling between Wellington and Auckland 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. Thus it is correct to treat each purpose-specific trip in the context of an assumption on what proportion of the travel time saved is transferred to leisure and what is transferred to work activity. Only then can we assign an accurate weighted value of transferring time for a particular trip.

A17.2 Microeconomic Theory of Time Allocation

A17.2.1 Introduction

The present state of development of microeconomic models which include the time-duration of consumption derives from Becker (1965), Johnson (1966), Oort(1969), DeSerpa (1971, 1973), Evans (1972) and de Donnea (1972, 1973a,b). Reviews of this theory are given in Gronau (1976), Bruzelius (1979) and MVA et al. (1987). Forsyth (1980) introduces taxation effects into the economic model.

The basis of microeconomic theory is that the consumer maximises his/her utility (the satisfaction deriving from consumption activities) subject to various constraints. The basic theory ignores the fact that there is a time requirement for consumption and that for some activities this time requirement will be fixed, and for some there will be a minimum time requirement. Introducing the time duration of consumption into modelling theory provides a mathematical basis for the value of time transfers between activities, as set out in the following paragraphs.

A17.2.2 Mathematical Specification

The general mathematical specification of the utility maximising behaviour of the consumer is:

Maximise (utility) $U(x)$, subject to $g(x) \leq b$

where $x_1 .. x_i ... x_n$ is a vector of commodities

and $g(x) \leq b$ is a functional constraint.

This problem can be respecified as one of unconstrained optimisation of the corresponding Lagrangian function $L(x, \lambda)$:

Maximise $L(x, \lambda) = U(x) - \lambda [g(x) - b]$

where λ is the Lagrangian multiplier and corresponds to the marginal utility of relaxing the constraint.

The first order conditions for an optimum are obtained by partial differentiation of L with respect to each decision variable and setting the result to zero, that is:

$$U^1 - \lambda g^1(x) = 0 \text{ for each } x_i$$

This optimisation process involves a number of assumptions concerning the utility function and the constraints which are not discussed in this Appendix.

The functional form of utility models has been specified in a variety of ways. The basic form is $U(x,l)$ where x is a vector of commodities and l represents leisure time. In this form, time is divided into paid work and leisure. Recognising that people obtain some utility or disutility from work, aside from the payment they receive, the utility function can be extended to include paid work time (t_w). The utility maximising behaviour is constrained by income, as follows:

$$p.x - g(t_w) - I \leq 0$$

where p is a vector of prices for commodities x;
$g(t_w)$ is the compensation for work which is usually expressed as $w \,.\, t_w$, (where w is the wage rate), and I is other non-labour income.

This form implies that payments are made in proportion to hours worked. This is a questionable assumption in the case of salaried employees and others paid on a task-fulfilment basis.

This basic model does not acknowledge the time duration of consumption, and a number of extensions have been proposed to remedy this. The current consensus appears to lie with models of a form first proposed by DeSerpa (1971), developed by Bruzelius (1979) and later by MVA et al. (1987), with a model form as follows:

Maximise $U(x,t,t_w)$, subject to constraints:

(i) $p.x - w.t_w - I \leq 0$ (income constraint) [λ]
(ii) $t_i + t_w - T = 0$ (time constraint) [μ]
(iii) $t_i > t_i^*$ (activities with minimum times) [ι_i]
(iv) $t_i = t_i^*$ (activities with fixed times)
(v) $t_w > t_w^*$ (minimum work time constraint) [ϕ]

where T is the total time available, and * denotes a minimum allowable value.

This specification therefore envisages that some activities have fixed consumption times (constraint iv), and some have minimum times (constraint iii). The total time for all consumption activities plus work must equal the total time available (constraint ii). There is in fact no need to specify (iv) as these activities can be subtracted from T to give a modified total time budget.

Activities i can be divided into those for which the minimum time constraint is binding, which have been termed "intermediate" activities in the literature (intermediate between work, often regarded as fixed, and leisure for which there is no constraint). So the inclusion of a leisure time variable, l, is no longer specifically required.

A17.2.3 Marginal Utility

The marginal utilities of relaxing these constraints, indicated against each above in [ ], are:

- λ marginal utility of additional income
- μ marginal utility of increased total time
- ϕ marginal utility of decreasing minimum work hours
- ψ_i marginal utility of decreasing the time requirements for activity i.

Respecifying the model as a Lagrangian function, the unconstrained optimisation function is:

$$Max\ L = U(x,t,t_w) - \lambda(p.x - w.t_w - I) - \mu(T - \Sigma t_i - t_w) - \phi(t_w^* - t_w) - \Sigma\psi_i\,(t_i^* - t_i).$$

The rate of commodity substitution (RCS) between one item and another, that is the amount of one commodity that a person would be prepared to forgo for an extra amount of another commodity, is expressed as the ratio of their marginal utilities. So the RCS between an activity and income is a measure of the value of time spent in that activity.

A17.2.4 Conditions for Optimality: Values of Transferring Time

By taking the partial derivatives of L with respect to x_i, t, and t_w, setting these to zero, and dividing by the marginal utility of income, λ, we get first order conditions for optimality:

1. $(1/\lambda).\, \partial U/\partial x_t = p_i$ — the marginal value of consuming good i is equal to its price p.

2. $(1/\lambda)\, \partial U/\partial t_i = \mu/\lambda - \psi_i/\lambda$ — the marginal value of time spent consuming good i is the difference between the marginal utility of increasing the total time budget less the marginal value of decreasing the minimum time constraint on activity i.

3. $(1/\lambda)\, \partial U/\partial t_w = -w + \mu/\lambda - \phi/\lambda$ — the marginal disutility of work is compensated by the wage rate plus the marginal value of decreasing minimum working hours less the marginal utility of increasing the time budget.

The value of transferring time from work to another activity can be obtained from the second and third conditions as:

$$(1/\lambda)(\partial U/\partial t_i - \partial U/\partial t_w) = w + \phi/\lambda - \psi_i/\lambda$$

The value of saving work time, to the employee, is therefore the after tax wage rate *only* if there is no minimum time constraint on working hours ($\phi = 0$) and no time constraint on the substituting activity ($\psi_i = 0$).

Returning to the second condition above, if time is transferred between two activities i and j, then the value is given by:

$$\psi_j/\lambda - \psi_i/\lambda;$$

that is, the value of transferring time depends on whether there are binding time constraints on the activity from which time is being transferred (such as travel) and the activity that time is being transferred to. If the activity which time is being transferred to is leisure, then the value of transferring time is ψ_i/λ, and this is what is generally being referred to when the term "value of travel time" is used in transport appraisal.

If there is no minimum time constraint on activity j, then $\psi_j = 0$, and the value of time spent in activity j is μ/λ, that is the RCS between income and time, or the WTP to increase the time budget. (This is sometimes referred to as the resource value of time, not to be confused with shadow pricing of behavioural VTTS to obtain a resource value.) It follows that if $\psi = 0$, then activity j is a pure leisure activity. Transferring time from one such leisure activity to another has no value, as the value for both activities is μ/λ.

If the situation being studied is a time transfer between a travel activity and an activity without a binding time constraint, then the value ψ_i/λ can take a range of values, depending on the marginal utility of the travel activity:

(i) If travel has a marginal disutility, which is the most common case, then the value of transferring time from travel to the other activity will be greater than μ/λ ($\psi_i > \mu$).

(ii) If travel has some positive marginal utility, the value of transferring time may still be positive, provided this utility is less than the resource value ($\mu > \psi_t > 0$).

(iii) If travel has no binding time constraint, then it is by definition a leisure activity, and there is no value in transferring the time to another leisure activity.

A18. VALUE OF TRAVEL TIME SAVINGS FOR CHILDREN

A18.1 Introduction

The VTTS for children has been treated arbitrarily in the past. The matter first appears in an official recommendation in the *Mathematics Advisory Unit Note 179* issued by the UK DoT. In that paper, the VTTS for children under 16 is assumed to be ⅓ of the adult rate.

The AASHTO *Manual on User Benefit Analysis* (1977) makes no mention of VTTS for children, although the advice contained in that recommendation applies implicitly to adult travellers.

The UK practice was continued in New Zealand in Roading Division CM98, Roading Directorate RD144, based upon reviews of practice made by Read (1971) and Cox (1983). In the NRB Economic Appraisal Manual, TR9 (Bone 1986), and in the Transit New Zealand Project Evaluation Manual (1991), no specific advice is given on the treatment of children.

A18.2 Review of Literature

A review of the literature reveals little or no empirical or theoretical study of either behavioural or resource values of time saving for children. Some of the more recent studies in the UK and Netherlands have identified differences in behavioural VTTS between students and working adults, an effect which appears to be related primarily to time constraints. These findings provide perhaps the only basis presently available for suggesting a treatment of the time savings for school age children.

A18.3 Issues Involved in VTTS for Children

Establishing a VTTS for children overlaps with other VTTS issues, in particular the question of individual or group valuation implicit in driver VTTS, and also variation in VTTS with trip purpose.

A precise definition of "child" is also required, as it is quite possible that different treatment may be appropriate for pre-school, primary school and secondary school age children. The upper age limit has been equated with the minimum driving age, but again this is arbitrary and of course this age around the world ranges between 15 and 18, with New Zealand at the lower end.

There is also some ambiguity concerning survey definitions of vehicle occupancy. Reported vehicle occupancy surveys seldom indicate whether children have been included or excluded and, for children aged 12-15, it is difficult to make this distinction without stopping and interviewing vehicle occupants.

In the absence of specific empirical research on VTTS for children, a pragmatic approach can be suggested using the general findings from recent VTTS studies and accepting the limitations of survey methods and data.

If empirical studies using WTP theory were to be carried out on children, there is an immediate problem of interpretation of cost trade-offs, as fares will often be paid by an adult. However this is a methodological rather than a theoretical problem. Children can be considered to be persons with a very low income (pocket money and part-time job earnings). As a large portion of their subsistence is paid by others, they do have discretionary spending within confined limits, although these limits will vary depending on the rules imposed by parent/guardian. The methodological problems are in fact similar to those which arise in VTTS studies of adult travel but in a more extreme form (limited choice sets, income effect, etc.).

A18.4 Proposed Interim Approach for VTTS for Children

The first step is to consider the main circumstances in which children travel. The following can be conjectured, and are discussed further below:

- Infants travelling in the care of their guardian(s) - the travel in this case is essentially at the initiative of the adult(s) and any VTTS for the child will be subsumed within the VTTS for the adult. However, it is possible that the responsibility for an infant will affect the disutility of travel time for the adult and the presence of infants in the family may also be a significant discriminating factor in the time constraints of the adult members.

- Children being driven to/from school or kindergarten - in this case the primary driver trip purpose is either "serve passenger" (the child) or the school trip may be a minor part of a linked trip, such as journey-to-work. The driver VTTS will include the adult's VTTS in making the school trip but will probably not include any urgency (or lack of it) experienced by the child.

- Children travelling unaccompanied to/from school or other trip purpose. In these cases, any VTTS resides essentially with the child, although some residual cost may be conjectured to lie with the guardian through concerns regarding safety (depending on whether just the opportunity value of time savings or the disutility of the trip is also included). Modes will be walk, cycle and public transport - the latter being of considerable importance as children comprise a sizeable share of public transport demand. This category probably constitutes the main problem area.

A18.5 Household Type Effects

Both the Netherlands study (Bradley & Gunn 1990) and the UK studies (MVA et al. 1987) found some differences in VTTS according to household composition. This form of classification picks up differences in disposable income once the main family outgoings (like mortgage payments or rent) have been deducted, and also differences in the number and scheduling constraints of daily activities. Persons with fewer and less strictly scheduled activities exhibit lower VTTS on average than those with more and strictly scheduled activities. Families with children tend to have lower ratios of disposable to nominal income in comparison with single adults and couples without child dependants. These families will often have two working adults and the added time pressures of organising child care and transportation, which will tend to increase their VTTS.

In the UK studies, with the base case being working age non-student members of two person households engaged in fixed working hours employment, a variation of ±10% was recommended for single or multiple person households, a 25% reduction for retired persons, and a 20% reduction for students.

The Netherlands studies were more revealing about the effects of family circumstances. For commuting trip purpose, households with one or more children (number of workers unspecified) exhibited a 20% higher VTTS than households of two adults, one working. However the difference between households with children and households with two adults, both working, was much less, only 5.5% higher.

A further analysis of the Netherlands data, reported by Bradley & Gunn (1991), showed households composed of working adults and children to have the least "free" time, and to have 10 to 11% higher VTTS for male adults and 3.5% to 5.8% higher for female adults, than for the base case. These ranges apply to commuting, business and "other" trip purpose categories. There are no specific results for trips on which children accompany adults, so any disutility of in-travel time effects are averaged out.

A18.6 Children's Individual VTTS

Differences in the VTTS experienced by the driver and other family members are similar to the case of infants. However, as children grow older, the case for allowing a VTTS for any changes they experience in utility becomes stronger. At the transition from secondary school to driving age, the UK studies indicate that students have a VTTS some 20% lower than that of employed adults. This gives a "fix" at one end of the age range, assuming that the average non-child student is of average age 18.

As children grow older they become more able to undertake economically "useful" tasks, and also start to achieve some significance as consumers in their own right. A pragmatic approach in the absence of better information would be to assume a linear increase in the VTTS from 0% of the adult value as children emerge from the infant stage, say at age 5, to 80% of the adult value at age 18.

On this basis, primary school age children (5 to 13) would be attributed with a VTTS of 25% of the adult value; secondary school children (13 to 16) with 55% of the adult value; and older students with 80% of the adult value. Overall, children under the legal driving age for a full licence (16 in New Zealand) would be attributed with a VTTS of 33.8%, say ⅓ of the average value.

Thus it is possible to rationalise the arbitrary assumptions made in the past with the limited available empirical evidence.

A18.7 Recommendations

On the above basis, our recommended advice for inclusion in the PEM is summarised as follows:

- In vehicle occupancy surveys, pre-school infants should be excluded or separately identified in survey counts. Likewise, school age (5 to 16) children should be separately identified, although some uncertainty is recognised in visual recognition of secondary age children.

- Alternatively, all occupants other than infants may be counted, in which case the standard traffic composition tables and time values in Appendices A4 and A3 of the PEM should be modified to allow for child occupants. These tables would be modified after undertaking controlled sample surveys for different road and traffic classes.

- Children age 5 to 16 should continue to be attributed with a VTTS of ⅓ that of the VTTS for adult work commuters.

- Further empirical research addressing the VTTS of children is not considered to be a high research priority in terms of additional useful knowledge or certainty likely to be gained for research expenditure. However, the effect of household composition, including the presence of children, on VTTS for adults should be incorporated within the research programme.

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