Implications of Selected Urban Road Tolling Policies for New Zealand

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Land Transport New Zealand Research Report No.270

ISBN 0-478-25381-8
ISSN 1177-0600

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*Wallis, I. 2005. Implications of selected urban road tolling policies for New Zealand. †*Land Transport New Zealand Research Report No. 270.* 130 pp.

* Booz Allen Hamilton, PO Box 10926, Wellington
† formerly Transfund New Zealand Research Report series

Keywords: economics, modelling, New Zealand, pricing, roads, road tolling, toll schemes, traffic, urban areas

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Acknowledgments

The project was undertaken with support and inputs from a Liaison Group comprising representatives from:

- Ministry of Transport (Martin Glynn, Nick Sargent)
- Land Transport NZ, previously Transfund NZ (Simon Whiteley, Ian Melsom)
- Transit NZ (Colin Crampton, Karen Boyt)
- Greater Wellington Regional Council (Tony Brennand)
- Tauranga City Council, on behalf of Local Government NZ (Brian Hodge)

In addition, advice and comments were provided by the Peer Reviewer, David Bray (Economic and Policy Services, Australia). We acknowledge their assistance.

Abbreviations & Acronyms

ALPURT	Albany–Puhoi Realignment
ASC	Alternative Specific Constant
BAH	Booz Allen Hamilton
BCR	Benefit:Cost Ratio
Beca	Beca Carter Hollings & Ferner
BOOT	Build, Own, Operate, Transfer
CATI	Computer-Assisted Telephone Interviewing
FB	First Best (pricing)
FTM	Fixed Trip Matrix
GST	Goods & Services Tax
GWRC	Greater Wellington Regional Council
LTMA	Land Transport Management Act 2003
LTNZ	Land Transport New Zealand
MCLA	Melbourne City Link Act
NLTF	National Land Transport Fund
NLTP	National Land Transport Programme
NPV	Net Present Value
NT	No toll
O-D	Origin–Destination
PEM	Project Evaluation Manual, Transfund NZ
PM	Profit-Maximising (pricing)
PPP	Public Private Partnership
PV	Present Value
RP	Revealed Preference
RUC	Road User Charges
SABV	Semi-Adaptive Boundary Value
SB	Second Best (PRICING)
SCBA	Social Cost-Benefit Analysis
SP	Stated Preference
SRMC	Short Run Marginal Cost
TCC	Tauranga City Council
TGM	Transmission Gully Motorway
TRC	Toll Road Constant
TUTI	The Urban Transport Institute, Melbourne
VOC	Vehicle Operating Costs
VTM	Variable Trip Matrix
VTTS	Value of Travel Time Savings
WTP	Willingness to Pay
WTSM	Wellington Transportation Strategic Model

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Executive Summary

Background and Context

Over recent years, interest has been increasing, in New Zealand and internationally, in the application of tolling policies to contribute to the funding of major new road infrastructure projects in larger urban areas. Typically these policies result in a major tolled route being inserted in a network of 'free' roads. Often private sector funding is involved.

To date, the experience with urban road toll routes in New Zealand has been very limited, the main (past) examples being the Auckland and Tauranga Harbour Bridges. Potential tolled roads now being considered in New Zealand include two in the Auckland area (ALPURT B2, PenLink), the Tauranga Harbour Link scheme, and the Wellington Transmission Gully route. Australia is ahead of New Zealand in the development of urban toll roads and is one of the world leaders in this field. Toll roads are already operational in Sydney (several schemes, including the Sydney Harbour Bridge/Tunnel), Melbourne (the City Link project) and Brisbane.

In New Zealand, such toll routes are being seen as one solution to the desire to increase urban road network capacity, in the Auckland area in particular, in a situation of constrained funding. The issue has been given greater prominence through the recent introduction of the Land Transport Management Act 2003 (LTMA), which will facilitate the implementation of toll roads subject to certain conditions (including that the schemes must essentially relate to new infrastructure, not tolling of existing roads). In response to this Act, Transit New Zealand has been working intensively over the last two years both in formulating policies and approaches in relation to toll roads, and also in undertaking market research, traffic modelling and economic/financial appraisal of potential toll projects. As noted by Transit NZ: *"Funding repaid from user tolls is the only genuine alternative that increases funding levels over time. It is therefore the only alternative that allows more projects to be built."*

A number of significant implications arise from the differential charging policies inherent in having individual tolled routes in an urban network of 'free' routes:

- **Traffic distribution/assignment** – some trips that would use the new route if 'free' are deterred from its use by the charges, and continue to use the existing network. Hence the extent of congestion relief provided by the new route is less than would be achieved if it were 'free'.
- **Environmental** – this traffic distribution towards existing roads will typically (but not necessarily) result in adverse environmental impacts (relative to a 'free' new route).
- **Economic** – this sub-optimal traffic distribution typically (but not necessarily) also has adverse effects on road user benefits and hence the underlying economic

merits of the project (although the costs to the public sector are generally reduced).

- **Financial** – the existence of more-or-less parallel free routes limits the maximum feasible toll charges, the associated toll revenue and hence the 'fundability' of the new road project.

Hitherto, studies have been very limited (in New Zealand or internationally) on the importance of these issues for urban road tolling policies; and on their implications for decisions on whether a proposed new route should be tolled, how the toll charges should be set, the design of the scheme, etc. In particular, relatively little attention appears to have been paid to the implications of tolling on scheme economics and on overall socio-economic welfare. This project was designed to fill this knowledge gap through combining both theoretical considerations and empirical evidence, and providing better information to assist policy formulation on urban road tolling in the New Zealand context.

Project Objectives and Scope

The **overall objective** of the project was *"To examine the implications of road tolling policies applying to selected major roading projects in larger urban areas, and in particular the traffic, environmental, economic and financial implications."*

The project involved three main tasks:

- Review of New Zealand and international practice on traffic modelling and economic evaluation for urban toll road schemes, and formulation therefrom of a best practice framework and guidelines for assessing tolling policies.
- Selection of appropriate toll road case studies in New Zealand and internationally (principally Australia); examination of modelling and evaluation studies for these schemes; and summarising findings for each scheme on the traffic/environmental and economic implications of tolling.
- Drawing together the outcomes from these two tasks and developing conclusions on:
  - best practices in urban toll road traffic modelling and economic appraisal,
  - issues to be considered in the development of potential new toll schemes, including whether or not to toll, price setting, design aspects, etc.,
  - comments on the development work undertaken to date for proposed New Zealand tolling schemes, in particular relating to the traffic and economic implications of tolling.

The project did not attempt to provide a comprehensive review of all aspects of New Zealand urban tolling policies and scheme proposals. In particular:

- The project focus was on the implications of tolling individual schemes (rather than making them 'free') in the context of an otherwise 'free' urban road network: it was not concerned with appraising the intrinsic economic merits of proposed toll schemes (relative to not constructing these schemes).

- The main emphasis in practice was on new road proposals under consideration as tolled schemes, because economic evaluations had been undertaken for a selection of such schemes, and because the New Zealand toll road legislation allows tolling for new road schemes only. However, most of the issues discussed and conclusions drawn would be generally applicable to the tolling of existing roads.
- The project was not concerned with the merits of alternative funding sources (in particular private sector funding), nor with the implications of tolling policies for the overall New Zealand road programme and project priorities.

General Merits of Tolling Selected Urban Roads

The project's review of international literature on urban road pricing policies indicated that the economic case for pursuing selected urban road tolling policies (involving individual tolled routes in a network of 'free' roads) is generally rather weak:

- Any selected road pricing policy will raise only a small proportion of the revenue and generate a small proportion of the welfare benefits that would result from 'first best' pricing, i.e. when all roads are priced on an economic optimal (marginal social cost) basis. By contrast, some other urban road pricing policies (e.g. parking surcharges, toll rings) can generate a much larger proportion of the welfare benefits achieved through 'first best' pricing.
- Of the selected road pricing policies generally examined by analysts, welfare-maximising ('second best') policies perform substantially better in welfare terms than revenue-maximising (or profit-maximising) policies:
  - Revenue-maximising policies are generally inferior in welfare terms to an 'all free' network;
  - Welfare-maximising policies are superior to an 'all free' network, but generate only a small fraction of the welfare benefits from 'first best' pricing.
- However, welfare-maximising toll levels are typically less than half the level of revenue-maximising tolls, and raise in the order of only half as much revenue.
- The structure of prices under welfare-maximising policies and that under revenue-maximising policies are also in conflict: revenue-maximising prices involve higher tolls when the free road is most congested, and when demand elasticity is lower; welfare-maximising policies involve the converse.

Tolling of selected (new) roads in an urban network results in diversion of some potential traffic to the alternative (old) routes. Typically in urban situations, this causes both road user disbenefits and environmental disbenefits: the tolled road is under-utilised and the remaining network over-utilised relative to the economic optimum. This effect is often substantial: for some schemes the extent of traffic diversion can be as much as half (or more) of the users of the road if it were free; and the economic benefits of the scheme can reduce by a broadly similar proportion.

Suitability of Roads for Selected Tolling: Economic Performance Indicators

While, in general, the economic case for selected road tolling policies appears rather weak, the evidence assembled in this project clearly identifies that some urban road schemes are much more 'suitable' for tolling than others. The prime measure of economic 'suitability' proposed is the (net) revenue raised through tolling relative to the resulting loss in economic welfare (NPV).

It is recommended that a set of economic-based performance indicators should be developed and applied to assess the suitability of proposed road schemes for tolling from an economic standpoint, i.e. trading-off the revenue impacts of tolling against the economic and related (traffic, environmental) impacts. The revenue raised**:**NPV loss measure suggested above would be one of the primary indicators in this set. Recommendations on the full set of such indicators are provided in the report.

Toll Scheme Modelling and Evaluation Methods

Our review of case studies and modelling/evaluation practices for tolling schemes in New Zealand and Australia has highlighted that:

- In many cases, there has been little or no consideration of the relative merits (from traffic and economic aspects) of tolled and untolled options, and even less consideration of alternative toll levels or structures: this is particularly the case for the Australian schemes.
- In the relatively few cases where both tolled and untolled options have been assessed on a comparable basis, deficiencies in both the modelling and evaluation aspects cast considerable doubt on the veracity of the outputs provided.
- Minimal post-implementation market research, which could potentially be used to develop improved ex ante forecasts and economic appraisals, has been carried out.
- The practice guide developed by Transit NZ covering traffic/toll modelling aspects is generally sound, but would benefit from greater detail on a number of significant issues relating to tolling schemes.

The review of the various tolling case studies in this report has helped to identify the main areas of deficiency in current modelling/forecasting and economic evaluation procedures and practices for toll schemes in particular (as distinct from the 'standard' well-established procedures for road schemes in general). These main areas of deficiency (not all applying in all cases) are summarised in Table 1. Against each area, the table also sets out our recommendations on future practices, to overcome the identified deficiencies and to achieve best practices in the traffic modelling and economic evaluation of tolling schemes.

Table 1 Toll scheme modelling and evaluation methods – existing practices and recommendations.

Aspects	Comments on Existing Practices	Recommendations on Future Practices
A. OPTIONS FOR CONSIDERATION		
1. Range of scheme options	• Most scheme evaluations have given little or no consideration (in economic terms) to tolled v untolled options; and even less consideration to alternative toll levels and structures.	• For (potential) toll schemes, options evaluated should include No Toll and a range of Toll options • Toll options should cover a range of toll levels and structures (including revenue-maximisation, welfare-maximisation and demand management options).
B. MARKET RESEARCH METHODS (NZ SP Surveys)		
1. Vehicle occupancy	• Unclear whether survey results relate to driver only or to all vehicle occupants combined.	• Surveys/analyses should explicitly analyse how VTTS are affected by vehicle occupancy, and model traffic behaviour accordingly.
2. SP methodology	• Some doubts on validity/robustness of semi-adaptive boundary-value SP method.	• Suggest independent review of methodology prior to any further SP surveys.
3. Representation of route choices	• Some doubts as to whether alternative route scenarios presented in the SP survey are sufficiently realistic representations of the alternatives.	• Ensure questionnaire provides realistic depiction of tolled and untolled alternatives.
4. Use of RP data	• Research methods to date have not attempted to check or calibrate SP survey results against RP data.	• For any toll roads implemented, recommend that undertake an 'After' survey and recalibrate 'diversion curve' functions using these survey results.
C. TRAFFIC MODELLING ASPECTS		
1. Matrix selection	• Almost all NZ schemes have been modelled/evaluated on a 'fixed trip matrix' basis, although evidence suggests this can lead to substantial errors in the evaluation of user benefits, particularly in congested situations.	• Recommend that 'variable trip matrix' ('full response') methods be adopted for major schemes where congestion is/will be a substantial issue for any options. • It may be appropriate to use the Transmission Gully project as a case study and undertake several runs of the Wellington Regional model (WTSM) allowing different responses, to assess sensitivity of the results to the matrix modelling methods.
2. Network representation	• Modelling may not adequately reflect either the current network conditions or the future conditions with the toll road operational.	• Modelling should include calibration of traffic volumes and speeds against the existing network. • Future year modelling needs to consider potential network changes that may be made in response to the new route (e.g. speed limits, capacity reductions).
3. Assignment methods	• Traffic assignment methods (to reflect choice between toll route and alternatives) often do not adequately replicate the range of travel behaviour indicated by the VTTS distribution from the market research.	• It is highly desirable to ensure consistency between SP survey responses, traffic modelling and economic evaluation aspects. This issue may need to be addressed further in the selection of assignment and evaluation methods (e.g. incremental loading methods, reflecting the VTTS distribution).
4. Future demand forecasting	• Most modelling assumes that current behavioural cost functions (from SP survey) will continue to apply for future years.	• Modelling should allow for likely future changes in VTTS as real incomes increase (at minimum, by way of sensitivity tests).
5. Annualisation	• Modelling methods are often inadequate in deriving annual toll road usage, revenues and user benefit estimates from assignment outputs.	• Detailed traffic modelling is needed for at minimum 3-4 separate time periods (including weekends) that will adequately capture the current/future range of travel conditions. • Expansion/annualisation factors need to be selected appropriate to toll route traffic patterns rather than general traffic flows in area.
D. ECONOMIC EVALUATION ASPECTS		
1. Treatment of VTTS distribution	• Current NZ evaluation practice (as per PEM) is to apply a single average ('equity') VTTS in calculating user benefits of all schemes. This project has highlighted that, for toll schemes, this practice is likely to result in wide divergence between the estimate of user (dis)benefits and an estimate based on the observed (SP) distribution of VTTS: the use of the observed distribution would result in user disbenefit estimates for tolling much lower than those derived in the 3 NZ case studies.	• The use of a single average VTTS for assessing the economic implications of tolling schemes is likely to be highly misleading. • Recommend that a consistent modelling and evaluation approach be adopted, based on the behavioural distribution of VTTS derived from the market research (SP surveys).

Abstract

Over recent years, interest has been increasing in the application, in New Zealand and internationally, of tolling policies to contribute to the funding of major new urban road infrastructure schemes. The project examines, in the context of policy developments in New Zealand, the traffic, environmental, economic and financial implications of tolling policies applying to selected major road schemes in larger urban areas.

The three main tasks were:

1. To review New Zealand and international practice on traffic modelling, price setting and economic appraisal for urban toll road schemes, and to formulate therefrom a best practice framework and guidelines for assessing tolling policies.
2. To select, appraise and summarise relevant toll road case studies in New Zealand and internationally (principally Australia).
3. From these outcomes to develop conclusions on: the general merits of policies for tolling selected roads in urban networks; criteria appropriate for assessing the traffic and economic merits of tolling specific schemes; and best practices in urban toll road traffic modelling and economic appraisal.

1. Introduction

1.1 This Report

This report was prepared by consultants Booz Allen Hamilton under the Transfund New Zealand Research Programme 2004-05, and is published by Land Transport New Zealand in its Research Report series.

It provides an appraisal of the traffic, economic and related implications of tolling selected (generally new) roads in an urban network of 'free' roads.

1.2 Project Background and Context

To date, the experience with urban road toll routes in New Zealand has been very limited with the main (past) examples being the Auckland and Tauranga Harbour Bridges. It is notable that in both these cases there was no easy alternative route for most traffic.

Over recent years, interest has been increasing, in New Zealand and internationally, in the application of tolling policies to contribute to the funding of major new road infrastructure projects in larger urban areas. Typically these policies result in a major tolled route being inserted in a network of 'free' roads. Often private sector funding is involved. Potential tolled roads being considered in New Zealand include two in the Auckland area (ALPURT B2, PenLink), the Tauranga Harbour Link scheme, and the Wellington Transmission Gully route. Australia is ahead of New Zealand in the development of urban toll roads and is one of the world leaders in this field. Toll roads are already operational in Sydney (several schemes, including the Sydney Harbour Bridge/ Tunnel), Melbourne (the City Link project) and Brisbane.

In New Zealand, such toll routes are being seen as one solution to the desire to increase urban road network capacity, in the Auckland area in particular, in a situation of constrained funding. The issue has been given greater prominence through the recent introduction of the Land Transport Management Act 2003 (LTMA), which will facilitate the implementation of toll roads subject to certain conditions (including that the schemes must essentially relate to new infrastructure, not to tolling of existing roads). In response to the Act, Transit NZ has been working intensively over the last two years both in formulating policies and approaches in relation to toll roads, and also in undertaking market research, traffic modelling and economic/financial appraisal of potential toll projects. As noted by Transit NZ (2003 draft): *"Funding repaid from user tolls is the only genuine alternative that increases funding levels over time. It is therefore the only alternative that allows more projects to be built."*

A number of significant implications arise from the differential charging policies inherent in having individual tolled routes in an urban network of 'free'[1] routes:

- **Traffic distribution/assignment** – some trips that would use the new route if 'free' are deterred from its use by the charges, and continue to use the existing network. Hence the extent of congestion relief provided by the new route is less than would be achieved if it were 'free'.
- **Environmental** – this traffic distribution towards existing roads will have typically (but not necessarily) adverse environmental impacts (relative to a 'free' new route).
- **Economic** – this sub-optimal traffic distribution typically (but not necessarily) also has adverse effects on road user benefits and hence the underlying economic merits of the project (although the costs to the public sector are reduced).
- **Financial** – the existence of more-or-less parallel free routes limits the maximum feasible toll charges, the associated toll revenue and hence the 'fundability' of the new road project.

Also, the practical requirements of tolling schemes may lead to a different design of the scheme than if it were a free route (e.g. fewer access/egress points). Further, in cases where the private sector takes revenue risk for the new road, contractual arrangements with government often restrict other improvements to the transport system that may adversely affect usage of the route.

Hitherto, studies have been very limited (in New Zealand or internationally) on the importance of these issues for urban road tolling policies, and on their implications for decisions on whether a proposed new route should be tolled, how the toll charges should be set, the design of the scheme, etc. This project was designed to fill this knowledge gap, through combining both theoretical considerations and empirical evidence, and to provide better information to assist policy formulation on urban road tolling in the New Zealand context.

1.3 Project Objectives and Scope

The **overall objective** of the project was defined as:

> *To examine the implications of road tolling policies applying to selected major roading projects in larger urban areas, and in particular the traffic, environmental, economic and financial implications.*

The project scope was defined in terms of the three main tasks involved:

- Review of New Zealand and international practice on traffic modelling and economic evaluation for urban toll road schemes, and formulation therefrom of a best practice framework and guidelines for assessing tolling policies.
- Selection of appropriate toll road case studies in New Zealand and internationally (principally Australia); examination of *ex ante* (before) modelling/appraisal studies and (where available) *ex post* (after) evaluation studies for these schemes; and

[1] 'Free' in this report means no direct charge is made to users (but costs will have to be recovered in some other form).

summarising findings for each scheme on the traffic/environmental and economic implications of tolling.

- Drawing together the outcomes from these two tasks and developing conclusions on:
  - best practices in urban toll road traffic modelling and economic appraisal,
  - issues to be considered in the development of potential new toll schemes, including whether or not to toll, price setting, design aspects etc.,
  - comments on the development work undertaken to date for proposed New Zealand tolling schemes, in particular relating to the traffic and economic implications of tolling.

The project had restricted terms of reference and therefore does not attempt to provide a comprehensive review of all aspects of New Zealand urban tolling policies and scheme proposals. In particular:

- The project focus was on the implications of tolling individual schemes (rather than making them 'free') in the context of an otherwise 'free' urban road network. It was not concerned with appraising the intrinsic economic merits of proposed toll schemes (relative to not constructing these schemes).
- Further, the main emphasis in practice was on new road proposals under consideration as tolled schemes, because economic evaluations had been undertaken for a selection of such schemes, and because the New Zealand toll road legislation allows tolling for new road schemes only. However, most of the issues discussed and conclusions drawn would be generally applicable to the tolling of existing roads.
- The project was not concerned with the merits of alternative funding sources, and in particular private sector funding.
- Nor was it concerned with the implications of tolling policies for the overall New Zealand road programme and project priorities.

1.4 Project Liaison Arrangements

The project was undertaken with support and inputs from a Liaison Group comprising representatives from:

- Ministry of Transport (Martin Glynn, Nick Sargent)
- Land Transport NZ, previously Transfund NZ (Simon Whiteley, Ian Melsom)
- Transit NZ (Colin Crampton, Karen Boyt)
- Greater Wellington Regional Council (Tony Brennand)
- Tauranga City Council, on behalf of Local Government NZ (Brian Hodge).

In addition, advice and comments were provided by the Peer Reviewer, David Bray (Economic and Policy Services, Australia).

1.5 Report Structure

The detailed review work and case study analyses undertaken are documented in a number of appendices to the report (refer Contents page). The main body of the report then draws on the material in these appendices to provide an overview of the main findings on each aspect of the terms of reference.

The remainder of the report is arranged in the following structure:

- Chapter 2 – presents our literature and practice review of the key aspects of road tolling policies: it covers traffic modelling, pricing, and investment appraisal aspects. This chapter draws on material in Appendices A (Traffic Modelling Methods), B (Pricing and Investment Policies) and C (NZ Tolling Policies).
- Chapter 3 – provides our review of selected road tolling case studies in New Zealand and Australia, leading to the development of a set of performance indicators for tolling schemes. This chapter draws on detailed case study material outlined in Appendices D (New Zealand) and E (Australia).
- Chapter 4 – draws together and summarises all aspects of the project work and develops conclusions and recommendations.
- Appendices A to E – document the detailed review work and case study analyses.

2. Literature Review and Development of Practice Recommendations

2.1 Introduction

This chapter summarises our review of international (including New Zealand) literature and practices on key aspects of urban road tolling schemes, leading to the development of 'best practice' guidelines on these aspects. It covers the three main aspects addressed:

Section 2.2 Traffic modelling aspects, including associated market research aspects.

Section 2.3 Pricing policy aspects, including examining the economic welfare impacts of different toll pricing policies in the context of the overall urban road network.

Section 2.4 Economic appraisal aspects, focusing on the issues in assessing the differences in economic performance for a road scheme under different toll pricing policies (including in particular zero tolls).

The summary material in this chapter is supported by the more detailed material in Appendices A, B and C in particular.

2.2 Traffic Modelling Aspects

2.2.1 Overview

This section is concerned with the development of best practice methods of traffic modelling, focusing on those modelling aspects which are specific to (or of particular importance in) modelling of toll road schemes. These specific aspects include, in particular, market research methods to establish motorists' likely behaviour in choosing whether to use a toll road or an alternative route.

Our review of the relevant literature and practices undertaken as input to this task covers both New Zealand practices (refer Appendices C and D) and Australian practices (Appendix E).

Taking as a principal starting point the advice provided by Transit NZ (2003b) in its 'Finance and Toll Projects – Implementation Guide', the material relevant to traffic/toll modelling is summarised in Appendix C2 (Table C2.1 in particular of this report). We consider the advice given by Transit NZ is sound, and see little need to amend it. However, in several areas (e.g. Demand Response) it is very non-specific and thus of limited help to the analyst. The comments below are thus more in the form of amplification and expansion of this advice, rather than being in any way inconsistent with it.

Comments on specific toll road traffic modelling aspects are under seven headings:

- Market research into likely travel behaviour
- Traffic assignment methods
- Modelling of other behavioural responses
- Network representation
- Selection of time periods and annualisation factors
- Future demand forecasting
- Environmental impacts

In our view, it is important to undertake the traffic modelling and the economic appraisal aspects of scheme assessment on a consistent basis, using the same behavioural functions (this point is further discussed later). Given this, most of the following comments on traffic modelling aspects are equally applicable to the economic appraisal aspects (covered in Section 2.4).

2.2.2 Travel Behaviour Market Research

As noted in Table C2.1 (summarising the advice given in the Transit 'Implementation Guide'):

- User values of time are a key input to the generalised cost equation (combining travel time, VOC (vehicle operating costs) and toll charge) used to determine the costs of travel on alternative routes.
- SP (Stated Preference) surveys are generally the preferred approach to investigating motorists' trade-offs between travel time and toll charges and hence establishing values of time savings. Such surveys need to be disaggregated by market segment and vehicle type.
- Analysis of RP (Revealed Preference) data on the use of existing toll facilities may be an alternative to SP surveys in some cases, although there are considerable issues of transferability. (Before and After traffic surveys and modelling analyses on new toll routes may be a valuable means of checking the validity of travel time v cost trade-off functions derived from SP surveys, and if appropriate adjusting them in the light of actual behaviour.)

Several SP surveys to investigate motorists' likely behaviour in response to toll road schemes have now been undertaken in New Zealand: one was undertaken in the Wellington region (for the Transmission Gully scheme) in 1999, two in the Auckland region (for ALPURT B2 and PenLink), and one in Tauranga (for Tauranga Harbour Link) in 2004. The Transmission Gully survey is summarised in Appendix D2.3 and the ALPURT B2 survey in Appendix D1.3 of this report.

The three recent Auckland/Tauranga region SP surveys may be regarded as models of their kind, and each employed almost identical methodologies. They were undertaken by Dr Tony Richardson of The Urban Transport Institute, Melbourne (TUTI) for Transit NZ. An overview and commentary on the survey methodology is given in Appendix A12, and key results and further comment on the ALPURT B2 survey are given in Appendix D1.3.

Four main comments are made on the survey methodology itself (summarising the material in these appendices):

- The surveys explored motorists' trade-offs between travel time and toll charge, with no mention of any travel distance effects. As a result, it is unclear whether respondents have implicitly allowed for distance differences in giving their responses; and hence how any distance differences should be treated in the traffic modelling. (This is a potentially significant issue for both ALPURT B2 and PenLink, given the geography of these schemes.)
- The key question asked in the surveys was simply: *"If you had a choice between a free road and a toll road which took Y minutes less and cost C, which road would you choose?"* There must be doubt as to whether this question and the preceding description gave respondents a sufficiently clear picture of the differences between the tolled and untolled option (e.g. the route alignment, speed limits, potential congestion on the untolled route through Orewa). It may well be that, because of this rather abstract way in which the question was posed, the value found for the 'toll road constant' (TRC) in both surveys was very close to zero. Whether this would realistically reflect actual travel behaviour is debateable (for example, the 1999 Transmission Gully SP survey estimated a much larger TRC value).
- The survey questionnaire is somewhat ambiguous as to whether the respondent (vehicle driver) is responding on behalf of him/himself only, or on behalf of all vehicle occupants on the trip concerned. Hence, whether the resulting value of time savings are per driver hour only, or per vehicle hour (covering all occupants) is unclear. In practice, the values have been interpreted and applied per vehicle hour. There is no discussion and clarification of this point in the market research or traffic modelling reports (in which at minimum, we would have expected some analysis of the variations in value of time savings by vehicle occupancy).
- A number of expert researchers and practitioners in the use of SP methods in the transport sector question the validity of the semi-adaptive boundary-value survey methods used and the derivation of VTTS (Value of Travel Time Savings) from them, as the methodology is considered to produce biased results. A detailed appraisal of the methodology is beyond the scope of the current project, but there may be merits in such an appraisal given the importance of the surveys in the traffic, financial and economic modelling for potential toll roads in New Zealand.

In terms of the results from the three TUTI surveys, perhaps the most pronounced feature is the wide distribution of VTTS found. This has substantial implications for both the traffic modelling and economic evaluation aspects of toll scheme assessments, and further discussion in the context of economic evaluation is given in Section 2.4.3.

2.2.3 Traffic Assignment Methods

The main purpose of the assignment part of the traffic modelling is to forecast traffic volumes (and corresponding traffic speeds) on each part of the road network, and

particularly on the toll road: these in turn determine toll revenues.

For accurate forecasting of route choice between the toll road and alternative routes, taking into account the full range of behavioural preferences of potential users of the toll road is clearly important. This is reflected in the full distribution of VTTS and TRC values, and is particularly important given the wide distribution of VTTS noted above.

Hence an assignment method is required that best replicates the surveyed distributions. As suggested by Transit NZ in Table C2.1 (Appendix C in this report), the preferred approach is to use the 'pre-assignment' or 'diversion curve' method. 'Diversion curves' are developed based on the SP survey results and are then applied to traffic volumes by O-D (Origin-Destination) pair, with toll road usage thus depending on the network data (time and costs) for each O-D pair and the diversion curve characteristics.

The alternative method of reflecting toll route choice directly through a 'conventional' assignment process is unlikely to be as satisfactory, particularly given the wide VTTS distribution. (Greater Wellington's (GWRC) recent experience in modelling for the Transmission Gully scheme is consistent with this view. After trying to model route choice directly through the assignment process, it then reverted to the 'diversion curve' approach in order to obtain results more consistent with the SP survey findings.)

2.2.4 Modelling of Other Behavioural Responses

Traffic modelling (and evaluation) studies are often based on a 'fixed (vehicle) trip matrix' approach, i.e. the modelling is concerned only with route changes for a fixed O-D vehicle trip pattern in response to changes in the network conditions. This approach ignores other changes that take place in the real world in response to changes in network conditions, such as:

- peak spreading/contraction,
- trip end redistribution,
- modal shift,
- trip generation/suppression.

While this is an issue in all traffic modelling studies, it is perhaps particularly important in the context of toll road schemes:

- these other behavioural responses are likely to be more substantial in situations of significant congestion relief; and
- accurate traffic forecasting is especially important for toll roads as it determines toll revenues and scheme viability.

This issue is noted in the Transit NZ (2003a) 'Implementation Guide', although no guidance is provided there on the choice between the 'fixed trip matrix' approach and the 'full response' or 'variable trip matrix' approach (refer Table C2.1, Appendix C). The Land Transport NZ Project Evaluation Manual (PEM) gives rather more guidance, stating (in its Appendix A11) that *"Variable trip matrix techniques may be used to model the effects of induced traffic where high levels of congestion are expected in both the do minimum and project option networks".*

We note that the traffic modelling and economic evaluation work for the Tauranga Harbour Link scheme found that the total user benefits were sensitive to the future year matrix assumptions, suggesting that they would be similarly sensitive to the choice between 'fixed' and 'variable' trip matrix approaches.

Also we noted that, in its modelling for the Transmission Gully scheme (TGM), GWRC adopted the 'full response' approach, using the regional multi-modal model (WTSM). GWRC (Kelly 2004) found that:

- The implementation of the TGM proposal (with or without tolling) increased road traffic in the corridor in the order of 20%-25% (i.e. a very substantial effect, as a result of providing additional capacity).
- Allowance for the full range of behavioural responses considerably reduced the benefits of the TGM scheme (with or without tolling), compared with the 'fixed trip matrix' approach.

In our experience, the above findings are not inconsistent with findings from good modelling practice elsewhere. They serve to highlight the importance of considering the full range of behavioural responses (potentially including modal choice), particularly for tolling schemes in congested network situations, where tolls may be used as a form of demand management (and the evaluation should reflect the benefits thereby achieved).

2.2.5 Network Representation

Two separate points should be made here.

First, it is important that the modelled road network accurately replicates both base traffic volumes and travel speeds, and how these speeds will vary with changes in traffic volumes. This point is basic to any traffic modelling work, but its importance is enhanced for toll schemes as good revenue forecasts are required.

Second, future-year modelling of the situation with the toll scheme needs to allow for demand management measures expected to be taken in conjunction with the scheme, whether for revenue-raising reasons, environmental reasons or other. These measures may include capacity reductions, access restrictions, speed limits, etc. on the existing (by-passed) route.

2.2.6 Selection of Modelling Time Periods and Annualisation Factors

The modelling of several time periods and the expansion of the results to derive annual traffic volumes and revenue estimates is more critical in the case of toll roads than for traffic modelling generally, as:

- Good estimates of toll revenue are important for scheme financial assessments.
- The split of traffic between the toll road and alternative routes is likely to be sensitive to the level of traffic demand on the network (degree of congestion) and the differing mix of trip purposes by time of day/day of week.

We agree with the comments in the Transit NZ 'Implementation Guide' on this issue, (refer Table C2.1, Appendix C), which are:

- Modelling needs to separately consider periods with differing levels of congestion.
- Caution is needed in the derivation of aggregate revenue estimates from the modelled time periods, accounting properly for all non-modelled periods.

Our review of the traffic modelling work for the various New Zealand and Australian tolling schemes (Appendices D and E) indicates that the modelling in at least several of the cases does not meet these guidelines. In a number of cases, scheme traffic volumes and revenues are derived from peak period modelling only, applying a typical annualisation factor for traffic flows generally. This approach is likely to significantly overestimate toll road usage and revenues, as toll road traffic volumes would typically be more peaked than for the network as a whole. (The time savings from toll road use are generally greater when traffic volumes and congestion levels are highest.)

Depending on the traffic demand characteristics of the scheme, we would recommend that detailed traffic modelling should be generally undertaken for a minimum of three and preferably more separate periods (including weekends); and then expansion/ annualisation factors applied to these period results, based on the characteristics of the toll route traffic rather than of traffic volumes in general.

2.2.7 Future Demand Forecasting

Robust forecasting of demand changes in future years (over a 25-30 year forecasting period) is an important component of the traffic modelling/forecasting process for all major road projects. In the case of tolling schemes, robust forecasting (with sensitivity testing) is particularly important, as it determines toll revenues and hence the financial viability of the scheme.

The future year forecasting task will need to address:

- The overall future year traffic matrices, by model time period, as in all traffic modelling.
- The 'diversion curve' choice functions, that allocate traffic between the toll route and the alternative route. Apart from any effects resulting from changes in network conditions (increasing congestion over time, etc.), these functions are likely to vary over time with increases in real incomes, and hence in time savings v toll charge trade-offs. At the minimum, this should be the subject of sensitivity tests.

2.2.8 Environmental Impacts

The environmental impacts of tolling policies are a direct function of the effects of these policies on traffic volumes (and composition) and travel conditions (speeds etc.) on the various routes affected, as discussed in the above sections and elsewhere in this report. These environmental consequences should also be incorporated into the economic evaluation (discussed in subsequent sections) to the extent that they can be measured and valued.

In some cases, local environmental impacts associated with tolling policies may be quite substantial, especially when these policies involve:

- differences in scheme design as a result of tolling (e.g. omission of interchanges),
- restrictions or closures of existing roads, in order to encourage use of the toll route (for whatever reason),
- significant traffic diversion off the toll route and into environmentally sensitive areas (Tauranga Route K is a case in point, refer Appendix D4.2).

In general, the toll route case studies examined in this report pay somewhat limited attention to the environmental impacts of tolling policies.

2.3 Pricing Aspects

Appendix B of this report comprises a summary and review of international literature relating to the pricing of roads in an urban network, and particularly 'second-best' pricing approaches for selected roads in situations where the bulk of the network is unpriced ('free').

The studies reviewed are generally concerned with short-run pricing policies, i.e. assuming the current network capacity is fixed. To the extent they consider long-run pricing policies (i.e. in a context where capacity can be varied), such analyses are more relevant to the economic evaluation topic (considered in Section 2.4).

Typically the studies reviewed consider the following (short-run) pricing policies for the urban road network:

- All free roads (No Toll (NT)).
- 'First-best' pricing (FB), under which all roads are priced based on short-run marginal costs (this policy maximises overall economic welfare).
- 'Second-best' ('public') pricing (SB), where selected road(s) are priced to maximise economic welfare, given the constraint of an otherwise free network.
- Profit-maximising ('private') pricing (PM), where selected roads are priced to maximise user revenue, given the constraint of an otherwise free network.

The studies typically compared toll levels, traffic volumes, toll revenues, travel times (and user costs) and social welfare across the different policy options. To derive numerical estimates, the studies typically developed and applied models using:

- simplified road networks,
- typical road user cost functions,
- typical demand elasticities,
- typical distributions of motorists' values of time.

Some models used just a single time period, while others allowed for two different periods (peak/off-peak) with cross-elasticities between them.

The findings of the various studies are generally broadly consistent. The work by Verhoef & Small (2004) (Appendix B1) may be regarded as perhaps the most definitive work relevant to the present purposes. The main findings of relevance from this and the other sources reviewed may be summarised as follows:

1. Value of time heterogeneity

All results are sensitive to the assumptions made about the distribution (heterogeneity) of values of travel time savings (VTTS) across the motorist population; and most analyses allow some degree of heterogeneity. As noted in Appendix B2:

Our results demonstrate the importance of heterogeneity in value of time for evaluating congestion policies that offer pricing as an option. Generally, the existence of heterogeneity favours such policies because product differentiation then offers a greater advantage: those with high values of time reap more benefits from the high-priced option, while those with low values of time find it all the more important not to be subjected to policies aimed at the average user.

2. Economic (social) welfare

Assuming heterogeneity in VTTS, typical results in terms of overall economic welfare are as follows:

- SB is very much inferior to FB, but somewhat better than NT. On a scale where welfare on the free network (NT) is set at zero and that for the first best option at 100, SB welfare is in the order of 25%. (Results in Appendix B1 give 23%; in Appendix B2 up to 28%; in Appendix B4 a range 11% to 46%; in Appendix B7 'around one-third'). These estimates of SB performance are considerably lower if a homogeneous VTTS assumption is adopted.
- PM results in net welfare considerably less than SB, and below that for NT (Appendices B1, B2).

3. Toll levels and revenues

Typical results in terms of relative toll levels and revenues are:

- The toll levels for FB and PM are broadly similar (but noting that FB toll levels will vary with the degree of traffic congestion in particular).
- SB toll levels are typically less than half those under FB/PM.
- SB toll revenues are rather more than half the PM revenues, but both these are only a small fraction of FB revenues.

These results are illustrated in Figure 2.1. This shows (indicatively) the relative toll levels, toll revenues and economic welfare under the four pricing options of FB, SB, PM and NT.

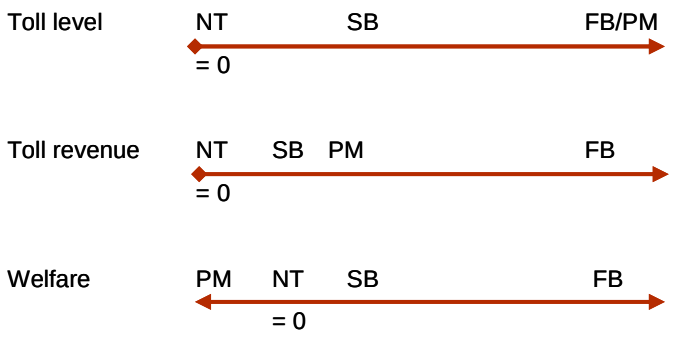

Figure 2.1 Relative performance of pricing policy options.

Note: Graph not to scale
PM = profit maximising; SB = second-best pricing; FB = first-best pricing; NT = no toll

The overall conclusions in terms of the pricing and merits of selected road tolling policies may be summarised as:

- Selected route pricing is very much inferior to first-best pricing of the whole network, both in economic welfare terms and in revenue-raising terms. (This result contrasts with results for other policies such as toll rings and parking surcharges, where welfare benefits may be a large proportion of those from first-best pricing: refer Appendix B3.) Selected route pricing may be inferior in welfare terms to an all-free network.
- If a selected route pricing policy is to be pursued, then second-best ('public') pricing is considerably superior in welfare terms to revenue-maximising ('private') pricing. Second-best pricing will result in toll prices and revenue levels in the order of half those for revenue-maximising pricing (refer Appendix B1).
- Revenue-maximising pricing typically results in lower net welfare than an all-free network.

These findings point to the conflicting objectives inherent in selective tolling policies:

- Introduction of tolls for all roads will tend to reduce the gap between motorists' prices and their marginal social costs, thus reducing total traffic volumes and increasing economic welfare.
- However, selective tolling typically diverts traffic from the tolled (usually uncongested) road to the free (usually congested) road, and may reduce welfare relative to an all-free situation.

  Introduction of profit-maximising tolls exacerbates this diversion, and typically reduces welfare below that in the all-free situation, but raises additional revenue.
- Second-best (public) pricing policies involve higher tolls where the free road is less congested and when the elasticity of demand is higher. Revenue-maximising

(private) pricing policies involve the opposite, i.e. higher tolls when the free road is more congested and the demand elasticity is lower (refer Appendix B5).

For all the road tolling case studies examined in New Zealand and Australia (Appendices D and E), insufficient information is available to be able to comment on the welfare and related implications of a range of alternative pricing policies for these schemes.

2.4 Economic Appraisal Aspects

2.4.1 Overview

In the context of this project, our principal interest under this heading is to review the literature and experience and to develop 'best practice' guidelines for the economic appraisal of different toll levels (including, in particular, toll v no toll) for urban road schemes being considered for tolling. In principle, the economic appraisal of toll options is no different from the appraisal of other (non-pricing) options for any scheme. The standard appraisal tool for such cases is social cost-benefit analysis (SCBA), as used widely in New Zealand (with detailed procedures being provided in the Land Transport NZ PEM). However, some key issues do arise in appraising tolling schemes that warrant particular attention.

The international literature that is reviewed in Appendix B provides almost no coverage of this topic in general, or of the particular issues that arise.

Further, in most of the New Zealand and Australian case studies examined (Appendices D, E), economic appraisals of tolled and untolled options on a comparable basis are not available, nor is there any discussion of key appraisal issues. Four partial exceptions to this are: the ALPURT B2 scheme, the Transmission Gully scheme, the Tauranga Harbour Link, and the Sydney F3-M2 link route. While in each of these cases, economic appraisals for the tolled and untolled options exist, some doubts arise as to their robustness and appropriateness, as discussed further in Chapter 3.

While the tolling project guidelines developed by Transit NZ (draft 2003b) provide a useful set of guidelines for the traffic/toll modelling of potential schemes, they do not include discussion of economic appraisal guidelines and issues. It may perhaps have been assumed that the economic appraisal process should directly follow the Land Transport NZ PEM procedures.

In general, using the PEM procedures for the economic appraisal of tolling scheme options in New Zealand would be appropriate. However, three particular points merit discussion here:

- The range of options for appraisal.
- The treatment of value of time savings.
- Appropriate economic performance indicators, in particular the composition and application of benefit:cost ratios.

2.4.2 Range of Options for Appraisal

The Transit NZ guidelines (draft 2003b) for toll projects specify, in relation to traffic/toll modelling, that:

- Assessment of the untolled case should be the starting point for appraisals.
- A number of other tests should be undertaken, aimed at the optimisation of the transport system. These tests may include revenue-maximisation, maximising traffic diversion from sensitive areas, and level of service optimisation.

We would support this approach, and consider that the various traffic/toll modelling tests undertaken should also be followed through to include the economic appraisal stage.

One 'optimisation' test that might usefully be added to the Transit list is (second-best) welfare optimisation. This provides a useful base against which the loss in welfare and gain in revenue of other options (e.g. revenue-maximisation) may be compared.

2.4.3 Treatment of Value of Time Savings in Appraisals

The usual practice adopted in the economic appraisal of roading schemes in New Zealand is to adopt averaged unit VTTS for motorists, differentiating only by vehicle type, trip purpose (work, commuting, other), and between drivers and passengers (refer PEM). The average values used in New Zealand are 'resource' values, derived from perceived or behavioural values by deducting an allowance for indirect taxation. Practices in many other countries are broadly similar in this regard to those in New Zealand.

This practice ignores differences in VTTS between motorists that are related to income, personal values and other differences: i.e. the same unit values are used for motorists from more affluent households (who are known to have higher VTTS on average) as for those who are less affluent. This use of such 'equity' values of time represents a departure from the general theory of basing economic appraisals on willingness-to-pay (WTP) (perceived/behavioural) values, after adjustment for the taxation component. This adoption of 'equity' values has both a pragmatic rationale (evaluation is easier) and some political rationale (to avoid favouring road schemes used by higher income groups).

The substitution of the full VTTS distribution (as established through WTP surveys) by a single mean value is not of major consequence for economic appraisal results in many situations. However, it is of major importance in the case of toll roads, and particularly so when comparing the economic merits of tolled v untolled options. For illustration, based on the SP survey of VTTS undertaken for the PenLink project (Richardson 2004):

- The mean VTTS for the whole survey sample was $14.40/vehicle hour.
- The mean VTTS for sub-samples comprising the low/medium/high thirds of the sample were $1.22, $7.77 and $31.76/vehicle hour respectively.
- If the overall mean value was used in the economic appraisal, time savings to all motorists would be valued at $14.40/hour.
- If the effect f the toll was to cause one-third of users (i.e. those with the lowest values of time) to divert from the toll road to the free road, those users would

perceive time disbenefits valued on average at $1.22/hour. This is less than one-tenth of the mean value for all motorists of $14.40/hour.

- Given that the principal benefits/disbenefits of tolling generally relate to motorists' time savings, this implies in this case that use of an 'equity' value of time would overestimate the perceived disbenefits of tolling to those diverted by about ten times. Other groups would also experience time (dis)benefits from tolling, and hence the overall disbenefit overestimate would be less than this factor, but still very substantial.

This is a major issue for the economic appraisal of toll schemes. The extent of the potential distortions associated with the use of 'equity' values of time is directly related to the spread of the behavioural VTTS distribution. (This same point was noted, from a different perspective, in Section 2.3 in that assumptions about the distribution of VTTS are important in assessing the welfare and other impacts of toll pricing policies.)

We would recommend that:

- The economic appraisal of toll roads (and most particularly of different tolling policies) should be based on the distribution of values of time consistent with users' WTP/behavioural values (as established through SP surveys or other means).
- A consistent set of assumptions on VTTS distributions should be used in both the traffic modelling and economic appraisal steps in toll road assessment. These steps need to pay particular regard to reflecting the distribution of behavioural VTTS.

2.4.4 Economic Performance Indicators

This section comments on the use of benefit**:**cost ratios as indicators of toll road performance, and how these ratios are most appropriately defined and interpreted. (Further discussion on toll road performance indicators more generally is given in Chapter 3.)

The 'standard' benefit**:**cost ratio (BCR) used in the economic appraisal of New Zealand road schemes is the ratio:

*Present Value (PV) of public benefits **:** PV of road authority costs*

Public benefits may accrue to road users and to other parties. The major user benefits of most road projects are travel time savings, vehicle operating cost (VOC) savings and accident savings. Costs include both capital costs (land/property, construction, etc.) and operating/maintenance costs. Both benefits and costs are measured in resource terms (i.e. net of GST, duties and indirect taxation). A project is regarded as worthy of execution ('economic') if its PV benefits exceed its PV costs, i.e. its BCR exceeds 1.0 (reference: PEM Sections 2.14, 2.15, A5.1.3).

In the case of toll schemes, the toll charges reduce the effective project costs paid by the road authority, and reduce the benefits received by these who use the road. In terms of benefits, the toll charges reduce the benefits to road users in two ways: for those motorists who continue to use the toll road, benefits are reduced by the extent of the toll charge; while for those who decide to divert to a free road, travel time and perhaps

vehicle operating costs are likely to increase. The tolls are effectively a transfer charge between those motorists who pay them and the roading authority.

In economic (resource) terms, the effect of the tolling scheme is to reduce overall public benefits to the extent of the loss of benefits by those who divert back to the free road (are 'tolled off'). The NPV of the scheme would thus reduce to this extent (and to the extent of any costs associated with toll collection, which are ignored in this simplified exposition).

In terms of benefit**:**cost ratios, one possible BCR measure is the ratio:

*PV gross public benefits**:**PV gross road authority expenditures*

Using this measure the gross benefits are calculated without deduction of the toll payments (these being regarded as a transfer payment and hence ignored in this resource estimation). The gross expenditures are calculated again without deduction of the toll funding contribution. This measure might be referred to as the 'resource' or 'unleveraged' BCR.

An alternative BCR measure is the ratio:

*PV net public benefits**:**PV net road authority expenditures*

In this case, relative to the above definition, the toll revenue is deducted from both the numerator and the denominator. This might be referred to as the 'leveraged' BCR.

The 'resource' BCR could be interpreted as reflecting the underlying economic merits of the project in 'pure' resource cost terms. On the other hand, the 'leveraged' BCR could be interpreted as better reflecting the merits of the (leveraged) project in competing for scarce roading authority funds.

This 'leveraged' BCR is arguably the more useful measure for most purposes of the ratio of public benefits to roading authority costs. It is closely analogous to the 'efficiency ratio' used in Transfund's 'Evaluation Procedures for Alternatives to Roading' Manual:

Efficiency ratio (ER) = PV Benefits/PV Net Costs to Government

In examining the various tolling case studies in Chapter 3 and in developing a set of performance indicators for road tolling schemes, we make use of both the 'unleveraged' and 'leveraged' BCR measures, as well as the NPV measure.

3. Case Study Commentary and Appraisal

3.1 Introduction

The second main task of the project was to select and draw on toll road case studies to illustrate and assess empirically the key implications (traffic, environmental, economic and financial) of selected tolling policies in urban areas, relative to an 'all free' network. The case studies focused on New Zealand and Australian toll road schemes (as noted earlier, Australia is one of the world leaders in the development and implementation of urban toll roads). It was hoped that, for some schemes, evidence would be available from both:

- *ex ante* appraisals (for traffic modelling and economic evaluation at the project planning stage); and
- *ex post* evaluations (reviewing the evidence on impacts after opening of the scheme, for operational schemes only).

Appendices D and E set out relevant material for tolling schemes in New Zealand and Australia that were case study candidates. Table 3.1 provides a brief summary of the evidence available for each candidate scheme, particularly commenting on the availability of traffic and economic data on tolled v untolled options:

- In New Zealand, economic evaluations are available for three projects: ALPURT B2, Transmission Gully Motorway and Tauranga Harbour Link. However none of these comprises an ideal case study:
  - for ALPURT B2 and Tauranga Harbour Link, traffic modelling and economic evaluation has been undertaken for both tolled and untolled options, although not making full use of the SP surveys of VTTS undertaken specifically for these projects;
  - for TGM, while economic evaluation has been undertaken for both tolled and untolled options, this is not well documented and it is thus difficult to judge its quality.
- In Australia, in several cases the detailed modelling and economic appraisal work did not consider the untolled option. In other cases, data on both tolled and untolled options are available, but not on comparable bases (as they may have been produced with different traffic models, and some years apart). In some of the few cases where comparable tolled and untolled appraisals have been undertaken, the results are being treated as commercially confidential and are not available.
- No useful *ex post* evaluation data were identified for any of the schemes.

Hence, high quality case studies suitable for use in this present project are scarce. The following discussion focuses on the four 'best' cases (in terms of data availability and quality):

- ALPURT B2
- Transmission Gully Motorway
- Tauranga Harbour Link
- Sydney F3-M2 Link Route

Table 3.1 Candidate case studies – summary of schemes and data available on tolled v untolled options.

Scheme Title	Scheme Summary	Available Data Summary
NEW ZEALAND ALPURT B2 (App. D1)	• 7.5km, 4-lane dual carriageway motorway • Construction cost c.$365M[1] • Construction started Dec 2004	• SP survey undertaken (2004) to establish VTTS. • Preliminary traffic modelling and economic appraisal undertaken for tolled/untolled options (Beca), but not directly using the SP results. • Used as case study.
Transmission Gully Motorway (App. D2).	• 24.3km, 4-lane dual carriageway motorway • Construction cost c.$830M (best estimate) • No decision to proceed yet taken	• SP survey undertaken (1999) to establish VTTS. • Traffic modelling undertaken (GWRC) for tolled/ untolled options, using GWRC regional model. • Economic appraisal undertaken (GWRC), focusing on the untolled option (only summary documentation available). Further advice provided by GW consultants on comparable results for tolled option. • Used as case study.
Tauranga Harbour Link (App. D3)	• 4-lane expressway scheme, including duplication of existing Harbour Bridge • Capital cost c.$210M • Currently open for consultation, re merits of charging tolls in order to advance construction date	• SP survey undertaken to establish VTTS. • Traffic modelling and economic appraisal undertaken (by Beca), using the Tauranga Transport Model. • Modelling/economic appraisal covered untolled and tolled options (range of toll assumptions), using fixed trip matrix approach (various estimates of matrix tested). • Used as case study.
PenLink Project	• Direct link road between Whangaparoa Peninsula and SH1 at Silverdale • Capital costs c.$70M	• SP survey undertaken (2004) to establish VTTS. • Detailed traffic modelling and economic appraisal not yet completed.
AUSTRALIA Melbourne City Link (App. E1)	• Capital costs c$1500M[1] • BOOT scheme • Scheme opened year 2000	• SP survey undertaken to establish VTTS. • Traffic modelling and economic appraisal of tolled scheme undertaken (*ex ante*). Said also to be earlier traffic/economic work on an untolled scheme, but on a different basis (and not readily available). • Some *ex post* traffic surveys undertaken and economic evaluation update currently in progress (but all for tolled scheme as operating).
Melbourne Mitcham – Frankston Freeway (App E2)	• To proceed as a BOOT project. • Still at planning stage – construction not yet started	• Several SP surveys understood to have been undertaken (by public authority and by private sector bidders). • Traffic modelling studies undertaken by private sector bidders (not readily available). • Traffic modelling and economic appraisal studies for tolled v untolled options said to have been undertaken by public authority, but not been released.
Sydney F3-M2 Link (App. E3)	• 4-lane/6-lane motorway, approx 8 km length • Capital costs in range $1700M-$2000M • Still at feasibility study stage	• Traffic modelling and economic appraisal undertaken for both 4-lane and 6-lane schemes, for both (revenue-maximising) tolled and untolled cases. • Used as case study.
Sydney Warringah Peninsula Access Upgrading (App. E4)	• 4-lane scheme, 5-8 km length • Capital costs in range $650M-$960M • At preliminary feasibility stage	• Main focus of traffic/economic modelling is on tolled options and financial results. • Some comparisons available on user costs for tolled v untolled options, but not full SCBA results.

[1] Monetary values for New Zealand schemes are NZ$; for Australian schemes are A$.

Our assessment of even these case studies, and their economic appraisals in particular, suggests that significant weaknesses exist in each case (e.g. they do not satisfy all the recommendations on traffic modelling and economic appraisal suggested in Chapter 2). We

have not attempted to adjust the reported results in respect of these weaknesses, and the results reported below should thus be regarded as illustrative only of the 'true' performance of the schemes.

We would also note here that very little evidence is available for the candidate schemes about the impacts of alternative tolling levels (or structures) on traffic modelling and economic evaluation results. Therefore our case study assessment has had to focus on tolled versus untolled options, without consideration of alternative tolling levels.

3.2 Commentary on Case Study Results

3.2.1 ALPURT B2 Scheme (Appendix D1)

Table 3.2 sets out the most recent (September 2004) economic evaluation results for this scheme, for both a tolled and an untolled option, in both cases relative to a 'do minimum' base. It also shows the key differences between the tolled and untolled options.

Table 3.2 ALPURT B2 scheme: summary of economic evaluation results (tolled v untolled).

All costs and benefits in NZ$M (2004), PV terms (5 years construction, 20 years operation) *All figures relative to a 'Do Minimum' base*			
Item	**Untolled Option**	**Tolled Option**	**Tolled – Untolled**
Gross Costs	245.1	268.6	+23.5 (+9.6%)
Gross Benefits	502.3	476.9	–25.4 (-5.1%)
Revenues	–	66.3	+66.3
Net Costs	245.1	202.3	–42.8 (-17.5%)
Net Benefits	502.3	410.6	–91.7 (-18.3%)
NPV	257.2	208.3	–48.9 (-19.0%)
BCR:			
On Gross Costs	2.05	1.78	–1.08
On Net Costs (Leveraged)		2.03	2.14

Source: Taken from Appendix D, Table D1.2

The main findings in relation to these results (i.e. reflecting the effects of tolling) in PV terms are:

- Both capital costs and recurrent costs increase, because of the costs of toll collection equipment and its operation/maintenance. Total (discounted) gross costs increase by $23.5M (9.6%).
- Gross benefits (i.e. excluding toll payments) reduce by $25.4M (5.1%). (This is perhaps a surprisingly small amount, given that the economic appraisal is said to be based on the assumption that tolling reduces the use of the new route by 20%.)
- Hence NPV reduces by $48.9M (19.0%).
- Total revenue raised by tolls is $66.3M.

- In net terms (i.e. after netting toll revenues off both costs and benefits), net costs are $42.8M (17.5%) lower than under the untolled option, and net benefits are $91.7M (18.3%) lower.
- The untolled BCR is 2.05. The tolled BCR on gross costs and gross benefits (the 'resource' BCR) reduces to 1.78.
- The tolled BCR on net costs and net benefits (i.e. the 'leveraged' BCR) is 2.03, virtually unchanged from the untolled figure.

The key implications of these findings in terms of the economic or financial impacts of tolling in this case appear to be that:

- Tolling raises $66.3M in gross revenue, or $42.8M in net revenue after allowing for the increased costs involved. By comparison, it reduces the intrinsic worth of the project (as measured by net welfare benefits, or NPV) by $48.9M. (This indicates that the tolling scheme is economically a rather inefficient way of raising revenue.)
- In terms of funding priorities, the leveraged BCR figures provide a priority ranking for use of Transfund's limited funding resources. As the leveraged BCR for the tolled option is almost unchanged from that for the untolled option, this indicates that tolling the scheme should not, per se, result in it being given higher priority for funding (but noting that tolling will reduce the amount of funding required, as reflected in the PV net costs, by some $43M or 18%).

3.2.2 Transmission Gully Motorway Scheme

Table 3.3 summarises the most recent available (2004) economic evaluation results for the scheme, showing both tolled and untolled options (relative to a base case) and the differences between them.

Table 3.3 Transmission Gully Motorway: summary of economic evaluation results (tolled v untolled).

All costs and benefits in NZ$M (2004), PV terms
Assumes 2016 opening, base year for discounting 2004 (?); 10% discount rate
All figures relative to base case (existing route)

Item	Untolled Option	Tolled Option	Tolled – Untolled
Gross Costs	362	383	+21
Gross Benefits	196 to 222	108 to 134	–88
Revenues	–	50	+50
Net Costs	362	333	–29
Net Benefits	196 to 222	58 to 84	–138
NPV	–166 to –140	–275 to –249	–109
BCR:			
On Gross Costs	0.54 to 0.61	0.28 to 0.35	–4.2
On Net Costs (Leveraged)		0.17 to 0.25	(4.8)

Source: Taken from Appendix D, Table D2.1 (columns A, G, H). Note that the results presented here are not fully consistent with those provided by GWRC (further details in Appendix D2).

The main findings in relation to these results, and particularly the effects of tolling, in PV terms are:

- (Gross) costs increase in the tolled case, by some PV$21M, representing the additional capital/recurrent costs associated with the tolling system.
- Gross benefits reduce in the tolled case, by PV$88M. This reflects the much reduced use of the new route when tolled.
- Hence NPV reduces by PV$109M.
- Total revenue raised from tolls is PV$50M.
- In net terms (i.e. after netting toll revenues off both cost and revenue totals), net costs are PV$29M lower than under the tolled option, and net benefits PV$138M lower.
- The untolled BCR is in the range 0.54 to 0.61. The tolled BCR on gross costs and gross benefits (the 'resource' BCR) is in the range 0.28 to 0.35, i.e. 50%-60% of the untolled figures.
- The tolled BCR on net costs and net benefits (i.e. the 'leveraged' BCR) is in the range 0.17 to 0.25, which is very much lower than the untolled BCR.

Key implications of these results regarding the economic and financial impacts of tolling for this scheme appear to be that:

- Tolling raises PV$50M in gross revenue or $29M in net revenue after allowing for the increased costs involved. By comparison, it reduces the intrinsic worth of the project (as measured by net welfare benefits, i.e. NPV) by PV$109M. This indicates that tolling of the project is economically a very inefficient way of raising revenue (e.g. relative to increasing petrol prices by an equivalent amount, in which case the net loss in welfare would be small).
- In terms of funding priorities, the leveraged BCR figures indicate the priority ranking for use of Land Transport NZ's limited funding resources. But as the leveraged BCR for the tolled option is substantially lower than the BCR for the untolled option, this casts major doubt on the case for Land Transport NZ to allocate funding at an earlier date to a tolled scheme than it would to an untolled scheme. (On a leveraged basis, the **untolled** scheme costs PV$29M more than the tolled scheme, but provides PV$138M more benefits, giving an incremental BCR of 4.8 for **not** tolling. This further indicates the economic superiority of the untolled scheme.)
- One measure of the financial efficiency of road tolling schemes is: the ratio *net toll revenue**:**NPV loss.* The higher this ratio, the stronger is the case for tolling. From the figures above (in Table 3.3) the ratio for TGM is (50-21)/109 = **0.27**. By comparison, the corresponding ratio for the ALPURT B2 scheme is estimated at 42.8/48.9 = **0.88** (refer Section 3.2.1).

Assuming here that the results given in Table 3.3 properly represent the economic impacts of the scheme (with v without tolls), these findings indicate that the case for tolling the TGM scheme is weak:

- Tolling results in a large loss of NPV (more than PV$100M).
- Tolling has a very low financial efficiency ratio (i.e. net toll revenue:loss of NPV).
- Tolling would be a very inefficient way of raising additional revenue for road construction and operation.
- Tolling substantially reduces the scheme's (leveraged) BCR and hence the case for Land Transport NZ to fund the tolled scheme earlier than the untolled scheme appears very weak.

The reasons that the case for tolling the TGM scheme is weak principally relate to the existence of the closely competing existing route. Except in situations of very high congestion (caused by high travel demand or traffic incidents), the existing route (with committed improvements) will be only a few minutes slower than the TGM route, because the level of congestion on the existing route will be limited by the existence of the new route alternative. Hence motorists' choice between the two routes will be very sensitive to toll levels, and the maximum toll revenue that can be raised will be very limited (in PV terms, maximum (gross) toll revenue is estimated to cover only c.13% of costs).

3.2.3 Tauranga Harbour Link

Table 3.4 summarises the most recent (May 2005) economic evaluation results for this scheme, showing both tolled and untolled options (relative to the base case) and the differences between them.

Table 3.4 Tauranga Harbour Link: summary of economic evaluation results (tolled v untolled).[1]

All costs and benefits in NZ$M (2004), PV terms (3.5 year construction, 21.5 years operation) *All figures relative to a 'Do Minimum' base*			
Item	**Untolled Option**	**Tolled Option**	**Tolled – Untolled**
Gross Costs	165.9	206.0	+40.1 (+24.2%)
Gross Benefits	511.8	172.3	–339.5 (–66.3%)
Revenues	–	114.5	+114.5
Net Costs	165.9	91.5	–74.4 (–45%)
Net Benefits	511.8	57.7	–454.1 (–89%)
NPV	345.9	–33.7	–379.6
BCR:			
On Gross Costs	3.09	0.84	–8.5
On Net Costs (Leveraged)		0.63	(6.1)

Source: Taken from Appendix D, Table D3.1

(1) Relates to 'base' test undertaken by Beca: other tolled tests resulted in higher BCR values for the tolled option.

The main findings in relation to these differences (i.e. reflecting the effects of tolling) in PV terms are:

- (Gross) costs increase in the tolled case, by some PV$40M, representing the additional capital/recurrent costs associated with the tolling system.
- Gross benefits (i.e. excluding toll payments) reduce by some $340M (66%). (This is perhaps a surprisingly large amount, given that the economic evaluation is said to be based on the assumption that tolling reduces the use of the Harbour Bridge by some 36%.)
- Hence NPV reduces by some $380M, and is a negative figure.
- Total revenue raised by tolls is some $115M.
- In net terms (i.e. after netting toll revenues of both costs and benefits), net costs are $74M (45%) lower than under the untolled option and net benefits $454M lower.
- The untolled BCR is 3.09. The tolled BCR on gross costs and gross benefits (the 'resource' BCR) reduces to 0.84.
- The tolled BCR on net costs and net benefits (i.e. the 'leveraged' BCR) is 0.63, which is very substantially lower than the untolled figure.

Note that these results represent a 'worst case' for the tolled option. Beca undertook a number of other modelling/evaluation tests involving different tolled options and different future year (but fixed trip) matrices. These various tests gave 'resource' BCR results in the range 1.2 to 2.0 (compared with 0.84 for the 'base' test used above) and 'leveraged' BCR results in the range 1.3 to 4.2 (compared with 0.63 above). The Beca evaluation report comments that these various BCR results are likely to be distorted because of two main factors:

- Use of the 'fixed trip matrix' approach (i.e. same matrix in the Do Minimum and the Option cases). The report indicates that this approach will tend to overestimate benefits in cases of the high BCR estimates, underestimate them in case of the low BCR estimates.
- Use of an average VTTS for all motorists, rather than a VTTS distribution, which would better reflect the perceived valuations of the different groups affected by tolling (e.g. distinguishing those who would divert to a 'free' route from those who would use the tolled route). This averaging will tend to considerably overestimate the perceived disbenefits of tolling (refer discussion in Section 2.4.3).

In the light of these factors, Beca suggests that more appropriate BCR estimates for the tolled scheme should be in the range 1.1 to 2.0 ('resource') and 1.2 to 3.2 (leveraged).

However, based on the Table 3.4 results, the key economic and financial implications of tolling in this case appear to be that:

- Tolling raises $115M in gross revenue or $74M in net revenue after allowing for the increased costs involved. By comparison, it reduces the intrinsic worth of the project (as measured by NPV) by $380M.

- The corresponding financial efficiency ratio total net toll revenue:NPV loss in this case is (114.5-40.1)/379.6 = **0.20**. This ratio is lower than that for the TGM project (0.27) and much lower than that for ALPURT B2 (0.88). (However caution is needed in interpreting these relative figures, as it is not clear that the three schemes have been evaluated on a consistent basis.)
- As with the TGM scheme, the leveraged BCR for the tolled case is substantially lower than the BCR for the untolled case. This casts doubt on the rationale for Land Transport NZ to allocate funding at an earlier date for the tolled scheme than it would to an untolled scheme. (On a leveraged basis, the incremental BCR of **not** tolling is 6.1, indicating the economic superiority of the untolled scheme.)

3.2.4 Sydney F3-M2 Link Route

Table 3.5 summarises the available economic evaluation results for this scheme (based on dual 3-lane motorway standards), showing both tolled and untolled options and the differences between them.

Table 3.5 Sydney F3-M2 Link: summary of economic evaluation results (tolled v untolled).

All figures relate to preferred route, dual 3-lane scheme, evaluated incremental to base case.
Figures in A$M (2003), PV terms, 7% discount rate

Item	Untolled Option	Tolled Option	Tolled – Untolled
Gross Costs	1282	1356	+74
Gross Benefits	1352	1090	–262
Revenues	–	750	+750
Net Costs	1282	606	-676
Net Benefits	1352	340	–1012
NPV	70	–266	–336
BCR:			
On Gross Costs	1.05	0.80	–3.5
On Net Costs (Leveraged)		0.56	(1.5)

Source: Taken from Appendix E, Table E3.1
Revenues as estimated by Booz Allen (refer Appendix E3 for details).
Note that operating/maintenance costs are included as (negative) benefits.

The main findings in relation to these results, and particularly the effect of tolling, are in PV terms:

- (Gross) costs increase in the tolled case by $74M, representing the additional capital costs associated with tolling.
- Gross benefits reduces in the tolled case by $262M (traffic volumes on the route are estimated to reduce by some 45%-50% with tolling).
- Hence NPV reduces by $336M.
- Total revenue raised from tolls is approximately $750M.

- In net terms (i.e. after netting toll revenues off both cost and revenue totals), net costs are $676M lower than under the tolled option, net benefits $1012M lower.
- The untolled BCR is approximately 1.05. The tolled BCR on gross costs and gross benefits (the 'resource' BCR) is significantly lower, at 0.80.
- The tolled BCR on net costs and benefits (i.e. the 'leveraged' BCR) is 0.56, substantially lower than the untolled BCR.

Key implications of these results regarding the economic/financial impacts of tolling for this scheme appear to be that:

- Tolling raises PV$750M in gross revenue or PV$676M in net revenue after allowing for the increased costs involved. By comparison, it reduces the intrinsic worth of the project (i.e. its NPV) by $336M.
- The ratio net toll revenue:NPV loss is one measure of the financial efficiency of tolling schemes. The ratio in this case (2.01) is significantly higher than the corresponding ratios for the other three case studies, indicating greater financial efficiency of this scheme.
- In terms of funding priorities, the leveraged BCR for the tolled option is substantially less than the BCR for the untolled option: this would cast doubt on any case for earlier public funding of the scheme as a tolled scheme. (This comment is made in the New Zealand funding context, but it is recognised that funding policies in NSW differ.)

3.3 Development of Economic Performance Indicators for Tolling Schemes

The foregoing case study assessment shows that some new road projects are more suitable in economic terms for tolling than are other projects. 'Suitability' in this context relates primarily to the loss in economic welfare from tolling relative to the (net) revenue raised.

Two major groups of factors influence such suitability:

- The relative competitiveness of alternative routes. This will be influenced by:
  - The length of alternative routes relative to the tolled route (if the tolled route is significantly shorter, this will allow higher toll charges to reflect the savings in vehicle operating costs).
  - The travel time savings on the tolled route (if time savings are only significant when the existing routes are highly congested, this will limit the tolls that can be charged at other periods).
  - Other factors relating to driver stress, route hilliness/bendiness, scenic views, etc., that may affect driver route choice (the 'toll road constant' effect).
- The traffic volumes that would use the toll route. With low volumes, a large proportion of toll revenues may go towards meeting the costs (capital and recurrent) associated with toll collection.

Current New Zealand tolling policies appear to have rather limited regard to economic (as distinct from financial) considerations in providing guidance on the selection of appropriate schemes for tolling (or on the appropriate levels of toll charges):

- The factors that the Minister of Transport must have regard for, in recommending the making of an Order in Council, do not specifically cover the economic merits of tolling (Transit NZ 2003a).
- The Transit-recommended coarse sieving process (see Appendix C1.4) for tolling schemes involves screening out candidate projects on grounds of:
  - small project size,
  - low expected traffic volumes,
  - expected low levels of toll revenues (if net toll revenues would contribute less than 10% of the required debt repayments).
- The Transit (2003b) 'Finance and Toll Projects – Implementation Guide' includes further description of pre-screening methods, traffic/toll modelling methods and business case development (including a 'value for money' assessment of alternative procurement options). However, the main focus of the business case 'value for money' assessment is on minimising expected scheme costs to government, rather than considering any trade-offs between these and benefits to scheme users.

Our review of the Australian case studies and practices indicates that Australian road authorities do not have any explicit policies or guidelines as to when schemes are appropriate for tolling, having regard to economic considerations. In both Sydney and Melbourne, decisions on tolling particular schemes appear to have been taken primarily on funding and policy grounds, without much regard to economic considerations. (In both cities, all current and proposed toll roads are being funded by the private sector, through BOOT or similar arrangements.)

Further, any relevant policy guidelines for other countries on tolling of urban road schemes, having regard to economic considerations, have not been identified.

As a step towards the development of possible policy guidelines, Table 3.6 sets out some potential performance measures relating to the economic performance of tolling schemes.

These measures essentially bring together the financial impacts and the economic impacts arising in relation to tolling schemes. They provide a 'package' of potential indicators, which may all warrant consideration in reaching decisions on tolling particular schemes.

Arguably the most important of these indicators (from Table 3.6) are:

A – impact on overall (resource) user benefits

D – economic efficiency of toll scheme in raising revenues

E – financial contribution of (net) toll revenues to overall scheme costs

F – financial efficiency of revenue–raising through tolls

Table 3.7 shows the performance of each of the four case study schemes against each of the Table 3.6 indicators, to the extent that the required data are readily available (and noting the deficiencies and comparability difficulties relating to these data).

Table 3.6 Potential tolling (economic) performance indicators.

Indicator	Interpretation/Comments
A. % reduction in PV Gross Economic Benefits (relative to 'free' option)	• Reduction in overall user etc. resource benefits as a result of tolling. • The lower the better.
B. % reduction in route VKT, at revenue-maximising toll (relative to 'free' option)	• Reduction in overall traffic levels using the toll road as a result of tolling (can potentially be translated into environmental impacts). • Generally the lower the better.
C. Revenue-maximising toll charge/VKT (light vehicles)	• Measure of financial impact on users of route.
D. PV Net Toll Revenues**:**NPV Change (relative to 'free' option)	• Measure of economic efficiency of raising revenues through tolling. ('Net' revenues allow for any increases in capital/operating costs.) • The higher the better.
E. PV Net Toll Revenues**:**PV Gross Costs (untolled)	• Measure of financial contribution of tolling to overall scheme costs. • The higher the better.
F. PV Toll-related Costs**:**PV Gross Toll Revenue	• Financial efficiency of revenue-raising (i.e. costs of raising revenue as proportion of total revenue raised). • The lower the better.
G. Change in BCR between Untolled (Resource) BCR and Tolled (Leveraged) BCR	• Measure of change in value for money achieved from roading authority expenditures. • The smaller reduction/larger increase the better.

Brief comments on the key results are as follows:

A – Overall user benefits change

The reduction in user benefits is highest for Tauranga Harbour Link (66%), followed by TGM (40% to 45%), reflecting the more closely competing nature of the existing routes. It is lowest for ALPURT, where the existing route is significantly longer and less attractive.

D – Toll revenue economic efficiency

This ratio is lowest for Tauranga Harbour Link, next lowest for TGM, indicating that in both these cases, they have relatively poor economic efficiency impacts relative to the revenue they raise. The ratio is highest for the Sydney F3-M2 link, indicating relatively high efficiency in this regard. Again the results are very much influenced by the closeness of competition from the alternative route.

E – Financial contribution of toll revenues

This ratio is lowest for TGM, highest for the F3-M2 link. The low value for TGM reflects both the nature of the competing route and the relatively high cost of the scheme.

F – Revenue-raising financial efficiency

These ratios are relatively high for all the three New Zealand schemes, reflecting that a substantial proportion (35% to 42%) of toll revenues are 'lost' in collection and related (capital and operating) costs. By contrast the ratio for F3-M2 is relatively low, at about 10%.

As noted earlier, these results have been based on the best information that was available, but should be treated as indicative only of the 'true' performance of the four schemes.

Table 3.7 Performance of case study tolling schemes against potential performance indicators.

Item/Indicator	Formula	ALPURT B2	Transmission Gully Motorway	Tauranga Harbour Link	Sydney F3-M2 Link
INPUTS					
PV Gross Benefits:					
1. Untolled		502.3	196 to 222	511.8	1352
2. Tolled		476.9	108 to 134	172.3	1090
PV Toll Revenues:					
3. Gross Revenues		66.3	50	114.5	750
4. Tolling Costs		23.5	21	40.1	74
5. Net Revenues		42.8	29	74.4	676
6. NPV Change		–48.9	–109	–379.6	–336
7. PV Gross Costs (untolled)		245.1	362	165.9	1282
BCR:					
8. Untolled (resource)		2.05	0.54 to 0.61	3.09	1.05
9. Tolled (leveraged)		2.03	0.17 to 0.25	0.63	0.56
INDICATORS					
A. % change in PV Gross Benefits	(1-2)/2	(–) 5.1%	(–) 40% to 45%	(–) 66.3%	(–) 24%
B. % change in route VKT		?	?		–44%
C. Toll charge/VKT		?	?		$0.44
D. PV Net Toll Revenues: NPV Change	5/6	(–) 0.88	(–) 0.27	(–) 0.20	(–) 2.01
E. PV Net Toll Revenues: PV Gross Costs (untolled)	5/7	17.5%	8.0%	44.8%	52.7%
F. PV Toll-related Costs: PV Gross Toll Revenue	4/3	34.7%	42%	35.0%	9.9%
G. Change in BCR	9-8	–0.02 (-1%)	–0.37 (-59% to -69%)	–2.46 (-80%)	–0.49 (–47%)

Source: Tables 3.2 – 3.5

4. Summary and Conclusions

4.1 The General Merits of Tolling Selected Urban Roads

This report presents an appraisal of the traffic, economic and related implications of tolling selected roads in an urban network of 'free' roads. While the case studies examined in the report all relate to proposed new road schemes, most of the report's findings are similarly applicable to the tolling of selected existing urban roads.

The increased pursuance of selected road-tolling policies for new roads in New Zealand and Australia over recent years appears to have been driven primarily by funding considerations (in that tolling 'stretches the roading budget further', enabling new road schemes to be constructed some years earlier than would otherwise be affordable within present budgets). Relatively little attention appears to have been paid generally to the implications of tolling on scheme economics and on overall socio-economic welfare.

Our review of international literature on urban road pricing policies indicates that the economic case for pursuing selected urban road tolling policies is generally rather weak, based on the following findings:

- Any selected road pricing policy will raise only a small proportion of the revenue and generate a small proportion of the welfare benefits that would result from 'first best' pricing, i.e. when all roads are priced on an economic optimal (marginal social cost) basis. By contrast, other urban road pricing policies (e.g. parking surcharges, toll rings) can generate a much larger proportion of the welfare benefits achieved through 'first best' pricing.
- Of the selected road pricing policies generally examined by analysts, welfare-maximising ('second best') policies perform substantially better in welfare terms than revenue-maximising (or profit-maximising) policies.
  - Revenue-maximising policies are generally inferior in welfare terms to an 'all free' network.
  - Welfare-maximising policies are superior to an 'all free' network, but generate only a small fraction of the welfare benefits from 'first best' pricing.
- However, welfare-maximising toll levels are typically less than half the level of revenue-maximising tolls, and raise only in the order of half as much revenue.
- The structure of prices under welfare-maximising policies and that under revenue-maximising policies are also in conflict. Thus revenue-maximising prices involve higher tolls when the free road is most congested and when demand elasticity is lower, but welfare-maximising policies involve the converse.

Tolling of new roads in an urban network results in diversion of some potential traffic to the alternative (old) routes. Typically in urban situations, this causes disbenefits to both road users and the environment: the tolled road is typically under-utilised and the remaining network over-utilised relative to the economic optimum. This effect is often substantial: for some schemes the extent of traffic diversion can be as much as half (or more) of the users of the road if it were free; and the economic benefits of the scheme can reduce by a broadly similar proportion.

4.2 Suitability of Roads for Selected Tolling: Economic Performance Indicators

While in general the economic case for selected road tolling policies appears rather weak, the evidence assembled in this project clearly identifies that some urban road schemes are much more 'suitable' for tolling than others. The prime measure of economic 'suitability' proposed in this context is the (net) revenue raised through tolling relative to the resulting loss in economic welfare (NPV).

Our recommendation is that a set of economic-based performance indicators (or criteria) should be developed and applied to assess the suitability of proposed road schemes for tolling (and potentially assess the level of tolls) from an economic standpoint, i.e. trading-off the revenue impacts of tolling against the economic and related (traffic, environmental) impacts. The ratio of revenue raised**:**NPV loss measure suggested above would be one of the primary indicators in this set. Provisional recommendations on the full set of such indicators are provided in Table 3.6 of this report.

4.3 Toll Scheme Modelling and Evaluation Methods

Our review of tolling schemes in New Zealand and Australia has highlighted the following points.

- In many cases, little or no consideration of the relative merits (from traffic and economic aspects) has been taken of tolled and untolled options, and even less consideration of alternative toll levels or structures. This is particularly the case for the Australian schemes.
- In the relatively few cases where both tolled and untolled options have been assessed on a comparable basis, deficiencies in both the modelling and evaluation aspects cast considerable doubt on the veracity of the outputs provided.
- Post-implementation market research has been minimal, but such research could potentially be used to develop improved *ex ante* forecasts and economic appraisals.
- The practice guide developed by Transit NZ covering traffic/toll modelling aspects is generally sound, but would benefit from greater detail on a number of significant issues relating to tolling schemes.

The review of the various tolling case studies in this report has helped to identify the main areas of deficiency in current modelling/forecasting and economic evaluation procedures and practices for toll schemes in particular (as distinct from the 'standard' well-established procedures for road schemes in general). These main areas of deficiency (though they do not all apply in all cases) are summarised in Table 4.1. Against each area, the table also sets out our recommendations on future practices, to overcome the identified deficiencies and to achieve best practices in the traffic modelling and economic evaluation of tolling schemes.

Table 4.1 Toll scheme modelling and evaluation methods – existing practices and recommendations.

Aspects	Comments on Existing Practices	Recommendations on Future Practices
A. OPTIONS FOR CONSIDERATION		
1. Range of scheme options	• Most scheme evaluations have given little or no consideration (in economic terms) to tolled v untolled options; and even less consideration to alternative toll levels and structures.	• For (potential) toll schemes, options evaluated should include No Toll and a range of Toll options. • Toll options should cover a range of toll levels and structures (including revenue-maximisation, welfare-maximisation and demand management options).
B. MARKET RESEARCH METHODS (NZ SP Surveys)		
1. Vehicle occupancy	• Unclear whether survey results relate to driver only or to all vehicle occupants combined.	• Surveys/analyses should explicitly analyse how VTTS are affected by vehicle occupancy, and model traffic behaviour accordingly.
2. SP methodology	• Some doubts on validity/robustness of semi-adaptive boundary-value SP method.	• Suggest independent review of methodology prior to any further SP surveys.
3. Representation of route choices	• Some doubts as to whether alternative route scenarios presented in the SP survey are sufficiently realistic representations of the alternatives.	• Ensure questionnaire provides realistic depiction of tolled and untolled alternatives.
4. Use of RP data	• Research methods to date have not attempted to check or calibrate SP survey results against RP data.	• For any toll roads implemented, recommend that undertake an 'After' survey and recalibrate 'diversion curve' functions using these survey results.
C. TRAFFIC MODELLING ASPECTS		
1. Matrix selection	• Almost all NZ schemes have been modelled/evaluated on a 'fixed trip matrix' basis, although evidence suggests this can lead to substantial errors in the evaluation of user benefits, particularly in congested situations.	• Recommend that 'variable trip matrix' ('full response') methods be adopted for major schemes where congestion is/will be a substantial issue for any options. • It may be appropriate to use the Transmission Gully project as a case study and undertake several runs of the Wellington Regional model (WTSM) allowing different responses, to assess sensitivity of the results to the matrix modelling methods.
2. Network representation	• Modelling may not adequately reflect either the current network conditions or the future conditions with the toll road operational.	• Modelling should include calibration of traffic volumes and speeds against the existing network. • Future year modelling needs to consider potential network changes that may be made in response to the new route (e.g. speed limits, capacity reductions).
3. Assignment methods	• Traffic assignment methods (to reflect choice between toll route and alternatives) often do not adequately replicate the range of travel behaviour indicated by the VTTS distribution from the market research.	• It is highly desirable to ensure consistency between SP survey responses, traffic modelling and economic evaluation aspects. This issue may need to be addressed further in the selection of assignment and evaluation methods (e.g. incremental loading methods, reflecting the VTTS distribution).
4. Future demand forecasting	• Most modelling assumes that current behavioural cost functions (from SP survey) will continue to apply for future years.	• Modelling should allow for likely future changes in VTTS as real incomes increase (at minimum, by way of sensitivity tests).
5. Annualisation	• Modelling methods are often inadequate in deriving annual toll road usage, revenues and user benefit estimates from assignment outputs.	• Detailed traffic modelling is needed for at minimum 3-4 separate time periods (including weekends) that will adequately capture the current/future range of travel conditions. • Expansion/annualisation factors need to be selected appropriate to toll route traffic patterns rather than general traffic flows in area.

D. ECONOMIC EVALUATION ASPECTS		
1. Treatment of VTTS distribution	• Current NZ evaluation practice (as per PEM) is to apply a single average ('equity') VTTS in calculating user benefits of all schemes. This project has highlighted that, for toll schemes, this practice is likely to result in wide divergence between the estimate of user (dis)benefits and an estimate based on the observed (SP) distribution of VTTS: the use of the observed distribution would result in user disbenefit estimates for tolling much lower than those derived in the 3 NZ case studies.	• The use of a single average VTTS for assessing the economic implications of tolling schemes is likely to be highly misleading. • Recommend that a consistent modelling and evaluation approach be adopted, based on the behavioural distribution of VTTS derived from the market research (SP surveys).

Appendix A:

Literature Summary & Review: Traffic Modelling Methods

A1: Using Values of Travel Time Savings for Toll Roads: Avoiding Some Common Errors

A2: Sydney ITS Course Notes

A3: Potential Pitfalls in Forecasting Travel Demand for Toll Roads: Experience in the US and Overseas

A4: Evidence-based Review: Attitudes to Road Pricing

A5: The Long and Winding Path to Private Financing and Regulation of Toll Roads

A6: A Retrospective on the Mexican Toll Road Program (1989-94)

A7: Credit Implications of Traffic Risk in Start-up Toll Facilities

A8: Demand Elasticity on Tolled Motorways

A9: Urban Tolled Roads and the Value of Travel Time Savings

A10: Values of Travel Time Savings in Personal and Commercial Automobile Travel

A11: Toll Roads – A Method for Estimating Usage and Revenue

A12: New Zealand Tolling Value of Travel Time (Stated Preference) Surveys

A13: New Zealand Toll Modelling Guidelines

A1. Using Values of Travel Time Savings for Toll Roads: Avoiding Some Common Errors

Reference: Hensher, D.A., Goodwin, P. 2004. *Transport Policy 11:* 171-181.

A1.1 Introduction

This is a key paper on issues associated with traffic forecasting for toll roads. Its main focus is on forecasting appropriate time values, which can then be used as a key input to traffic models, rather than in the traffic modelling task itself.

It covers the following main issues:

- Use of a distribution of travel time, rather than just a mean value (this is seen as the single most important issue);
- Treatment of values of time saving (VTTS) for car passengers;
- Growth in VTTS over time, to reflect increasing incomes etc.;
- Treatment of quality effects and other variables in calibrating demand models.

Its findings on each of these issues are summarised in the following sections.

A1.2 Treatment of Travel Time Distributions

The main points made may be summarised as follows:

- Motorists' VTTS govern their trade-off between time and costs when deciding whether or not to use a toll route.
- A considerable spread of VTTS occurs in any group of motorists. The distribution of VTTS may be established by SP methods (these methods are not addressed in Hensher & Goodwin's paper).
- VTTS distributions tend to be skewed towards the left (lower values), i.e. more motorists have VTTS below the mean than above the mean.
- In modelling the use of a toll route it is important to take account of the full VTTS distribution, not just the mean value (or any other 'representative' value): use of the mean value only will typically result in overestimation of the use of the tolled route.
- Four options are given as to how to take account of the VTTS distribution in modelling:
  - use the full distribution;
  - take a number of points on the distribution as representative;
  - take areas of the distribution and convert to a single weighted average VTTS;
  - use the unweighted average or median (in general the median will provide more realistic results than the mean, but is a poor substitute for use of the distribution).

- In practice, it is suggested that analysts might divide the VTTS frequency distribution into a number of areas (e.g. 4 equal areas, or areas each with a $1.00 band-width), calculate the weighted average for each area, and then use these weighted averages to represent separate market segments in the traffic modelling process.

A1.3 Treatment of VTTS for Car Passengers

The main points made may be summarised as follows:

- Toll road traffic studies focus on the vehicle rather than the driver, as tolls are almost always levied on a per vehicle basis.
- Very limited evidence exists internationally on VTTS for car passengers, and on how the presence of passengers in the car affects the time v cost trade-off functions inherent in decisions as to whether or not to use a tolled route.
- Such evidence as exists tends to indicate that vehicle VTTS increases with the number of passengers but less than proportionately.
- Thus, methods that assume that VTTS per vehicle increases in proportion to vehicle occupancy will tend to over-estimate usage of a tolled route.

A1.4 Growth in VTTS over Time

The main points made may be summarised as follows:

- VTTS is often expressed as a proportion of wage rates, and hence, in the future, values are assumed to increase in direct proportion to changes in real wage rates. If this assumption is built into traffic models, then increasingly less resistance to paying tolls is implied in future years.
- However, there is no theoretical reason why this relationship should apply in the future. There is now considerable empirical evidence that VTTS increases at a lesser rate than income: VTTS/income elasticities from a number of studies vary around 0.5, but with a considerable range and with elasticity values maybe varying by trip purpose. From the empirical evidence it is concluded that WTP for time savings has increased at between 25% and 75% of the rate of real income increases.
- Such estimates should be incorporated into toll road traffic models as an assumption that future VTTS increases in direct proportion to income is likely to overestimate future use of toll routes.

A1.5 Treatment of Quality Effects and other Variables in Calibrating Demand Models

The main points made may be summarised as follows:

- Many toll road traffic models are calibrated (to reproduce existing traffic levels on links) by using a single calibration parameter which is taken to represent VTTS.
- However, this approach is simplistic, as in practice factors other than time and cost differences will affect motorists' choice between alternative routes, e.g.:

  - travel time reliability,
  - proportion of time spent in free-flow v impeded conditions,
  - safety perceptions,
  - signage.
- Such factors should be taken into account in any SP surveys (separating each effect where possible) and in traffic model calibration.

One approach might be to specify an 'alternative specific constant' (ASC) for the toll route (relative to alternative roads), but this may not be entirely satisfactory. (For instance, travel on the existing route may be very congested and unreliable, and hence surveys of the existing situation may indicate a large ASC in favour of a new tolled route. However, if this is built, then the reliability of the existing route may substantially improve, and hence use of the toll route will be significantly lower than implied by this ASC value.)

A1.6 Conclusions

In conclusion, Hensher & Goodwin in their paper note that:

- The issues raised apply to traffic modelling generally, but are of particular importance in the case of forecasting usage of toll roads, where the consequences of forecasting error are more apparent and important (in terms of revenue collected).
- Most if not all of the issues discussed are likely, if not properly handled, to produce biases in the same direction, that is to overestimate toll road usage and revenue in both short and long runs.

A2. Sydney ITS Course Notes

Reference: Hensher, D.A. 1994. Sydney Institute of Transport Studies: The Australian Key Centre. Chapter 7, Course Notes: 18-31.

The notes provide a model for trade-offs between time and toll costs (assuming fixed cash-based tolls) based on Sydney evidence (1994).

Based on this model, a set of toll diversion curves is provided, relating the probability of choosing the toll route to:

- travel time savings,
- toll level,
- trip purpose/private commuting, business commuting, in-work travel, social-recreational travel).

(It is notable from these diversion curves that, at a toll of $1, there is a 50% probability of choosing the toll route for the following time savings:

- private commuting 8 mins (i.e. equivalent VTTS $7.50/h)
- business commuting 4 mins (i.e. equivalent VTTS $15/h)
- in-work travel 2 mins (i.e. equivalent VTTS $30/h)
- social/recreational 2.5 mins (i.e. equivalent VTTS $24/h))

The notes also emphasise that behavioural responses/sensitivity to tolls is likely to depend on how they are levied and who pays: the highest sensitivity will apply for cash transactions, paid by the user; lower sensitivity when the toll has been paid in advance, by the user; lowest sensitivity when the toll is paid by another party.

A3. Potential Pitfalls in Forecasting Travel Demand for Toll Roads: Experience in the US and Overseas

Reference: Dehghani, Y., Olsen, W. [December] 1999. Paper to *Transportation Research Board Annual Meeting.* 15pp. Washington DC.

A3.1 Introduction

This is one of the key papers available that reviews the state-of-the art in forecasting toll road usage.

Dehgani & Olsen note in their Introduction:

> *Traffic and revenue forecasts are required in order to plan for, design and assess the economic feasibility of a proposed toll facility. However, there is no state-of-the-art agreement among transportation researchers and practitioners regarding the best methodology for achieving such forecasts. Available and applicable research on the subject seems to be limited at the present time. Methods used in practice for preparing and analysing toll facility forecasts can be generally categorized as being either incremental or synthetic. The approaches mainly vary according to the method used to develop origin to destination trip tables for a given time period, trip purpose and travel market segment.*
>
> *Forecasts of traffic and revenue are important components of toll agency management as well as for bond financing agencies. Accurate forecasts are needed for financial planning, project evaluation, preparation of bond reports, bond rating agency reviews and to protect the interests of bond holders. In such applications, forecasting errors can easily have multi-million dollar impacts on the toll agency. Although this realization provides ample motivation for accuracy, the traffic and revenue forecaster's job is further complicated by potential pitfalls which can seriously impair the accuracy of such forecasts. Toll traffic and revenue forecasters also face a significantly different task responsibility than their colleagues who deal with typical design traffic forecasts for non-toll facilities. In toll facility forecasts, traffic projections for a project's initial years tend to be more important than design year (i.e. twenty year) forecasts.*

A3.2 Toll Road Traffic Forecasting: State-of-the Art

The paper notes and discusses the following five main steps in developing traffic forecasts for proposed toll roads:

1. *Development of baseline and future year trip tables (i.e. the number of daily trips expected to travel between relevant origins and destinations) by trip purpose and market segment (e.g. socio-economic class of trip maker).*

2. *Estimation of travel demand and traffic diversion analysis. Estimation of the value of travel time or 'willingness to pay' is an integral part of this step, which*

deals with the component of traffic that would find other travel routes rather than pay a toll.

3. *Calibration or validation of the overall toll forecasting procedures to agree with baseline (base year) conditions. The terms calibration and validation refer to procedures for adjusting travel forecasting model parameters in order to make modelled (synthetic) results agree with observed data.*

4. *Development of the transportation network attributes assumed to be in place by a designated future year.*

5. *Application of forecasting procedure and evaluation of toll traffic and revenue results.*

Step 2 (traffic diversion analysis) is of most relevance here, and is of particular importance for toll road forecasting (rather than traffic modelling in general). The following further comments relate to this step.

Traffic assignments

- The most common method of conducting toll diversion analysis is through capacity-restrained equilibrium assignment of vehicle trips onto a highway network.
- Separate assignments would typically be made treating the toll route as first free and then tolled: the difference in assigned volumes represents the traffic diversion due to tolls.
- For the toll situation, the normal travel time function is replaced by 'effective time', combining:
  - link travel time,
  - delay time due to queuing and service time at toll plazas,
  - a time penalty equivalent to the toll payment.
- This last term is calculated as the toll amount divided by the relevant average value of time (by time period, market segment etc.).

Diversion curves

- The diversion curve approach is an alternative method of preparing toll road traffic forecasts.
- Diversion curves show the toll facility's share of total demand versus the toll charge and the relative travel times on the tolled route and free alternative.
- The shape of the diversion curve is determined by using empirical data on the usage of tolled v non-tolled facilities, or by performing statistical analyses using RP of SP survey data. The use of SP methods for this purpose is growing in popularity.
- Once a diversion curve/model is established, it may be applied to split trip table cell values into trips on the toll route and those on competing routes.
- Recent attempts have been made to include toll facility diversion within the mode choice model component of the synthetic four-step modelling approach. This approach provides forecasts of toll facility demand for each category of vehicle occupancy.

A3.3 Potential Pitfalls in Toll Forecasting

Table A3.1 summarises Section 3 of the paper, which reviews potential toll forecasting pitfalls, under four main categories.

Table A3.1 Potential pitfalls in toll forecasting.

Category	Notes, Comments
A. Data Collection and Modelling Pitfalls	Relate to the collection of data and base year model calibration/validation.
1. Data Quality	Relates to input data quality (e.g. traffic counts, network characteristics, travel costs, car ownership).
2. Model Accuracy	Model calibration – fitting of statistical parameters to original data. Model validation – against traffic counts etc; may require use of model parameters from other studies.
B. Traffic Forecasting Considerations	Relate to traffic forecasting process, including forecasts for independent variables.
1. Assumed stability of system over time	
2. Uncertainty of land use forecasts	
3. Influence of land use lag	
C. Trip Maker and Travel Behaviour Factors	Relate to characteristics and travel behaviour of potential toll patrons.
1. Influence of ramp-up (public acceptance lag)	
2. Cultural differences regarding acceptance of tolls	
3. Peaking characteristics of toll facilities	Important issue, often over-looked. Usage of toll facilities in off-peak is usually significantly lower proportionately than in peak, because of lower congestion levels: usage of models based on peak situation only are likely to overestimate toll route usage.
4. Uncertainty in estimating VTTS	Important issue: use of single average unit VTTS can introduce large errors in toll forecasts.
5. Evasion of toll payments	
6. Public information lag	
D. External Considerations	Relate to factors generally outside the realm of the toll road forecaster.
1. Development of competing facilities	
2. Development of access facilities to route	
3. Political pressures	
4. Business motivations	

A3.4 Summary and Conclusions

The summary of the paper is as follows:

This paper has highlighted methods used by practitioners to prepare toll forecasts and identified potential pitfalls in the forecasting process. Toll traffic forecasting has traditionally been conducted by simplistic methods of analysis using travel cost or travel time diversion curves to determine the proportional share of total traffic that a new toll facility might expect to attract. However, traffic simulation models featuring capacity restrained equilibrium assignment are replacing the traditional approach. Traffic simulation models are evolving:

- *to include toll impedance in the path building and trip assignment steps*
- *to include toll facility diversion within the mode choice step of the four step process.*

While research has advanced during the last decade in the area of stated preference survey data collection and estimating the value of travel time, further research is needed to improve the toll forecasting process:

- *Further research is needed on the transferability of key toll forecasting variables over time and space. How can relationships and parameters such as the value of time validated for one study corridor in a particular country be transferred to another corridor in a different country?*
- *Further research is needed to help toll forecasters anticipate and cope with the various pitfalls identified in this paper. For example, failure to understand the phenomena of land use lag, ramp up and peaking produce forecasts that always overestimate toll traffic.*

A4. Evidence-based Review: Attitudes to Road Pricing

Reference: Lyons, G., Dudley, G., Slater, E., Parkhurst, G. [May] 2004. *Contract PPAD9/160/01.* 44pp. Final report to UK Department for Transport.

This paper comments on the limited evidence internationally on how different groups make trade-offs between time and costs in response to road pricing initiatives. It notes findings from two particular initiatives in the US:

- San Diego I-15 congestion pricing demonstration project. Found that WTP to reduce congested travel time was higher than indicated by previous stated results.
- Lee County (Florida) Bridge Tolls. Found that those most likely to avoid paying a toll (variable by time of day) tended to be:
  - more likely to have flexibility in their time of travel,
  - more likely to be retired,
  - significantly older,
  - less likely to be in high income categories,
  - more likely to have flexible working hours.

A5. The Long and Winding Path to Private Financing and Regulation of Toll Roads

Reference: Estache, A., Romero, M., Strong, J. [undated] 49pp.

This report, prepared by World Bank staff, focuses primarily on issues for toll roads in developing countries.

In respect to evidence on willingness-to-pay to use toll routes, it states the following:

> *More generally, the experience of Latin America and Eastern Europe shows that the standard assumptions that toll road users are willing to pay high tolls to compensate for reductions in travel time and vehicle operating costs are not as realistic as many academics would like them to be. This is a major problem since the tolls that users in these regions are willing to pay for may not be sufficiently high to attract private equity (or debt for that matter). Some practitioners are arguing that the standard traffic models used to forecast the demand for the roads are too mechanical and do not recognize well enough the behavioural changes that toll brings about. For instance, Piron reveals that for a series of toll road projects in France, a number of critical factors had been omitted from the traffic forecast models. These included the importance of the use of the toll for the overall budget of the private or commercial users of the facilities and the change in the willingness to pay with the distance to be covered by the user.*

A6. A Retrospective on the Mexican Toll Road Program (1989-94)

Reference: Ruster, Jeff. [September] 1997. Public Policy for the Private Sector*, Note No. 125,* 9pp. World Bank Group.

In reviewing Mexican experience with toll routes, this paper states that traffic study methodologies often suffered from the following:

- *Lack of analysis of specific traffic characteristics, including time and seasonal variations by type of vehicle, trip origins and destinations, and purpose and frequency of trips.*
- *Failure in projections to identify key economic parameters that would affect road usage, such as population, employment, per capita auto ownership, per capita and disposable income, and performance of key industrial indicators.*
- *Unrealistic growth rate assumptions for extended periods that, if realised, would have exceeded the capacity of the road.*
- *Failure to include an end-user learning curve or differences in tariff elasticity between end users.*
- *Over-reliance on increased demand due to the opening of interconnecting roads, the construction of which was often delayed or never undertaken.*
- *Underestimation of the congestion relief that the opening of the new toll road would bring for the toll-free option, and thus overestimation of the actual time savings of the new road.*
- *Insufficient attention to general conditions of alternative and feeder routes and the identification of factors influencing the traffic-carrying capacity of key sections.*
- *Inadequate and at times not readily accessible data from the Secretary of Communications and Transport for traffic studies.*
- *Though investors sometimes employed their own independent consultants, actual fieldwork was limited to one to two weeks of traffic surveys. This was often the result of insufficient time allotted to bidders and financiers between the date of release of the bid documents and the deadline for delivery of bids.*

A7. Credit Implications of Traffic Risk in Start-Up Toll Facilities

Reference: Bain, R., Wilkins, M. [August] 2002. Reprint from Standard & Poor's Rating Direct [6pp. unpaged].

This paper provides guidelines for evaluating toll-road traffic and revenue forecasts.

It includes a review comparing forecast and actual toll road traffic volumes for 32 schemes world-wide. When comparing first year traffic volumes, this review found that:

- Overall, traffic volumes were 73% of their forecast values.
- In only 4 of the 32 cases were traffic volumes higher than forecasts.
- In the studies done for Banks, the factor was 82% on average (i.e. 18% shortfall); while in the studies due for other parties the factor was 66% (34% shortfall).

For these case studies where comments were available on the reasons for predictive failures, it is noted that the reasons almost always lay external to the traffic models themselves, but stemmed from inaccurate or inappropriate assumptions made regarding key input variables. Typical reasons included:

- *High toll tariffs and a miscalculation regarding users' willingness to pay (especially frequent users such as commuters);*
- *Recession/economic downturn;*
- *Future-year land use scenarios that never transpired (including development build-out along the corridor that was less and/or slower than predicted);*
- *Time savings that were lower than expected;*
- *Improvements to competitive (toll-free) routes;*
- *Considerably lower usage by trucks; and*
- *Lower off-peak/weekend traffic.*

A8. Demand Elasticity on Tolled Motorways

Reference: Matas, A., Raymond, J-L. 2003. *Journal of Transportation and Statistics 6(2/3):* 91-108.

This paper analyses factors influencing traffic volumes on tolled motorways in Spain. Key findings include:

- Toll price elasticities for different motorway sections vary over a considerable range. Key factors influencing the elasticity are:
  - quality of the alternative free road (higher elasticity where there is a good uncongested alternative),
  - percentage of heavy vehicles on the alternative route (lower elasticity where higher percentage),
  - proportion of tourist traffic (lower elasticity for tourist traffic).
- Mean toll price elasticities were in the range –0.2 to –0.8, differentiated by the above factors.

A9. Urban Tolled Roads and the Value of Travel Time Savings

Reference: Hensher, D.A., Milthorpe, F.W., Smith, N.C., Barnard, P.O. [June] 1990. *Economic Record 66 (193):* 146-156.

The Hensher et al. paper describes a method for determining values of travel time savings for urban road users in the presence of varying levels of road tolls, for use in forecasting the demand for urban toll roads. The method was based on a utility maximisation framework using stated choice (SC) data. The paper was prepared in a context where there were no "tolled urban roads in any major urban area throughout the world".

In developing the methodology, it was seen as important that:

- The travel market should be segmented by trip purpose, given the expected variations in VTTS by purpose.
- Account should be taken of changes in the quality of travel time (e.g. in congested conditions) as well as the quantity.

The methodology was centred on the development and calibration of a route choice model, to reflect motorists' choice between a tolled route and 'free' route. The route choice function was based on a multinominal logit (MNL) model form. The model parameters postulated were travel time, toll costs and several cross-product terms (including delay times, frequency of trip, number of adults in car).

The SC survey elicited trade-offs between travel time (split between 'free' time and 'delay' time) and toll levels. 300 travellers were sampled in the Sydney metropolitan area, with each being given 7 sets of alternative trips to consider, based on the length/time of their current trip. The sample was segmented into 4 trip purposes: private commuter, business commuter, travel as part of work, other non-work related travel.

Relevant findings in terms of key parameters included:

- Total travel time was the best specification for the time effect, rather than separate weightings for 'free' time and 'delay' time.
- Values of time derived were very consistent with previous research results (mostly from RP sources), although higher than the values generally used for project evaluation in NSW at that time.

A10. Values of Travel Time Savings in Personal and Commercial Automobile Travel

Reference: Hensher, D.A. [July] 1995. Paper pp. 18-26 to Conference on Social Cost-Benefit Analysis, University of California, Irvine.

Hensher's paper includes a stated choice study to develop a valuation function for urban route choice, as input to traffic forecasting for the proposed Sydney Eastern Distributor Toll Route.

The SC survey offered respondents trade-offs between travel time (total time and delay time) and toll. Self-administered questionnaires were handed out to motorists using the relevant roads, and returned by post.

Reponses were segmented by five trip purposes: private commuter, business commuter, travel as part of work, non-work related travel, other personal business travel.

Values of time savings were derived as functions of the level of toll and duration of the trip (tolled section). Key findings included:

- For a given travel duration, VTTS increases with toll level,
- For a given toll level, VTTS decreases with the level of time saving,
- The significant correlation between toll levels and travel time requires that the valuation function has to allow for quadratic terms to derive reliable results.

A11. Toll Roads – A Method for Estimating Usage and Revenue

Reference: Johnston, D.K., Patterson, D. 1990. *Proceedings 15th ARRB Conference, Part 4:* 191-209.

A11.1 Introduction

Johnston & Patterson's paper presents improved methods for analysing and predicting motorists' route choice between a tolled road and a free road, focusing on use of a 'diversion curve' model and calibrating this from SP and RP surveys. The model was then applied to the newly-opened Logan Motorway (Brisbane), and modelled usage compared with observed usage.

A11.2 'Traditional' Approach

It notes the 'traditional' approach to estimating usage of urban toll routes through all/nothing traffic assignments, converting tolls to time penalties using average VTTS. It comments that this approach has several fundamental weaknesses, stemming from the use of an aggregate assignment toll to model complex route choice phenomena:

- Its aggregate nature does not allow examining toll impacts by different travel markets (with different VTTS and toll elasticities), nor for fine-tuning of tolling strategies.
- The testing of different toll levels is a time consuming and computer-intensive task.
- The readily available (all/nothing) assignment algorithms may produce very sensitive demand responses (particularly with limited networks).

A11.3 Proposed Approach

The paper puts forward a new approach designed to address the deficiencies of the traditional approach, and which produces a practical method of analysis based on consumer choice theory.

Based on consumer choice theory, a logit (binary choice) function is used to represent the probability of choosing the toll route rather than the existing route. The general form of this function is:

$$P_m = \frac{1}{1+e^{(-\beta_m \times dC_m)}}$$

where:

P_m = probability of using the toll route (market segment *m*)

β_m = constant

dC_m = difference in generalised cost between the two routes, expressed as $dT * VTTS_m + dD * VOC_m + Toll_m$

dT = travel time difference

$VTTS_m$ = perceived unit value of travel time savings
dD = distance difference
VOC_m = perceived unit vehicle operating cost
$Toll_m$ = toll change

Once the various inputs are determined, dC_m may be readily calculated for each origin-destination combination using a computerised network model.

To provide a general model for application purposes which allows for real-world behavioural variations, the above function was respecified in the following form (by market segment):

$$P = CAPT + \frac{1 - CAPT}{1 + e^{\lambda(dC+\delta)}}$$

The values of λ, δ and CAPT together define the shape of the diversion curve:

λ defines the slope of the curve
δ defines the horizontal shift in the demand curve (a non-zero value implies that the generalised cost specification does not adequately describe all the perceived costs of using the toll route)
CAPT defines the level of captivity to the toll route (generally zero except perhaps for business travel).

To apply this model to estimate demand on a toll road, it is necessary to:

- Estimate λ, δ, CAPT, VTTS and VOC
- Estimate total travel demand of potential toll users – by use of available trip matrices or through conducting roadside interview surveys etc.

A11.4 Logan Motorway Study Design

The objective of this study was to develop and prove a technique for the estimation of toll road usage and revenue which could then be readily applied to other toll road proposals. In particular, a better understanding was required of the various segments of the road travel market and how they trade-off travel time savings and toll charges. Other issues requiring better understanding included:

- how motorists perceive vehicle operating costs,
- how motorists share tolls among passengers,
- the extent to which tollways may encourage car pooling.

The study involved:

- A series of surveys before the Motorway opening, to provide a basis for forecasting usage and toll revenue.
- A series of surveys shortly after the Motorway opening, leading to comparisons of forecast and actual behaviour and appropriate adjustments to the model procedures if required.

The Before surveys involved:

- Roadside interview surveys, to develop a complete origin-destination matrix of potential toll road users.
- Household-based SP surveys of a subset of drivers intercepted in the home interview survey.
- Travel time surveys on major roads, as inputs to network coding.

The After surveys involved:

- A self-completion survey of motorway users.
- Follow-up household interviews with the drivers interviewed in the Before surveys.
- Updated travel time surveys.

From the Before SP surveys, VTTS by trip purpose were estimated using simple trade-off analysis. Once these values were established, the remaining variables (λ, δ, CAPT) were estimated by manual curve-fitting techniques. VTTS and diversion curves were derived for five separate trip purposes: home-based work, non-work, employer's business, commercial vehicles, external trips.

From the After surveys, estimates were made for motorway users of the VTTS (minimum values) implied by their behaviour in using the motorway at the given toll levels. It was found that these After VTTS values were approximately one-third higher than the values estimated from the SP surveys (i.e. motorists are significantly more likely to use the toll road than forecast). It was noted that one reason for this may be the reduced trip time variability experienced on the new route compared with use of the existing roads.

A new set of diversion curves was obtained by adjusting the Before VTTS estimates, but keeping the other three parameters unchanged. Application of these curves produced a second set of demand forecasts which matched closely to the observed traffic volumes.

One finding from the surveys is that the majority of motorists have no clear idea of the magnitude of their distance-related costs. Thus the inclusion of a distance-related cost term in the perceived generalised cost function is somewhat problematic. (This suggests that the SP surveys should perhaps explore trade-offs of time, tolls and travel distance, in order to establish perceived VOC values and better isolate VTTS.)

Other relevant findings included:

- Sharing of toll costs among vehicle occupants is not common.
- There is some evidence of higher car occupancy levels (including some car pooling) among motorway users.

A12. New Zealand Tolling Value of Travel Time (Stated Preference) Surveys

References:
1. Richardson, A.J. [March] 2004. *TUTI Report 27-2004* to Transit NZ.
2. Richardson, A.J. [December] 2004. *TUTI Report 37-2004* to Transit NZ.
3. Richardson, A.J. [December] 2004. *TUTI Report 36-2004* (October 2004). Paper to 26th Conference of Australia Institutes of Transport Research, Melbourne.

A12.2 Overview

References 1 and 2 above report on SP surveys undertaken by Tony Richardson (The Urban Transport Institute (TUTI)) for Transit NZ to establish valuations of travel time savings by motorists who would potentially use:

- ALPURT B2 scheme (Reference 1)
- PenLink (Whangaparoa) scheme (Reference 2).

Reference 3 is a conference paper by Tony Richardson that essentially reports on the methodology used in the two surveys.

The two surveys were identical in all important aspects. Both used the 'semi-adaptive boundary-value' stated preference (SABV SP) method. The methodology and the results from the ALPURT B2 survey are summarised in Appendix D1. The results for the PenLink survey are generally similar to those for ALPURT B2, although there are some significant differences (detailed review of these is outside the current project scope).

In terms of the survey methodology and its application for modelling the traffic implications of toll charges, the main points we would make are:

- The wide spread of the VTTS distributions obtained from the surveys underlines the importance of properly reflecting the distributions in the traffic modelling and subsequent economic evaluation processes.
- There is no mention of possible travel distance differences in the survey wording, nor are there any differences included in the trade-offs investigated. As noted in Section D1.3, it is thus problematic as to how any distance differences should be treated in the traffic modelling: this is a potentially significant issue for both ALPURT B2 and PenLink, given the geography of these schemes.
- Both surveys found very low values for the 'toll road constant' (TRC). As noted in Section D1.3, this may reflect the way the questions were posed, and may not properly reflect likely traveller behaviour when faced with the real-world alternatives for these two schemes.
- A number of expert researchers/practitioners in the use of SP methods in the transport sector question the validity of the SABV SP survey methods and the derivation of VTTS from them: the methodology is considered to produce biased results. A detailed appraisal of the methodology is beyond the scope of the current project; but there may be merits in such an appraisal given the importance of the surveys in the traffic and economic modelling for potential toll roads in New Zealand.

A13. New Zealand Toll Modelling Guidelines

Reference: Transit NZ. [August] 2003. Finance and Toll Projects – Implementation Guide. Draft Paper.

This draft Transit NZ Guide includes guidance on the traffic/toll modelling requirements and methods as part of the toll route feasibility assessment stage. The main modelling components and their desirable features are summarised in Appendix C2 (Table C2.1).

Appendix B:

Literature Summary & Review: Pricing & Investment Appraisal Policies

B1: Product Differentiation on Roads: Constrained Congestion Pricing with Heterogeneous Users

B2: The Value of 'Value Pricing' of Roads – Second-best Pricing and Product Differentiation

B3: Second-best Congestion Pricing in General Networks

B4: Multi-period Congestion Pricing Models and Efficient Tolls in Urban Road Systems

B5: The Economics of a Single Toll Road in a Toll-free Environment

B6: Long Run Effects of Partial Tolling Schemes

B7: Efficient Congestion Tolls in the Presence of Unpriced Congestion: A Case with Non-identical Road Users

B8: Which Consumers Benefit from Congestion Tolls

B9: Value Pricing: A Possible First Step Towards General Road Pricing Even in Germany

B10: Private Sector Involvement in Infrastructure Projects

B11: Welfare and Profit Divergence for a Tolled Link in a Road Network

B1. Product Differentiation on Roads: Constrained Congestion Pricing with Heterogeneous Users

Reference: Verhoef, E.T., Small, K.A. [January] 2004. *Journal of Transport Economics & Policy 38(1):* 127-156.

1. Verhoef & Small's paper examines the economic impacts of various pricing policies on a congested road network, allowing for elastic demand and heterogeneous users (with a distribution of VTTS).

2. Modelling uses:
   - simplified road networks, allowing different pricing policies on serial and parallel links
   - typical road travel cost functions
   - elastic demand functions
   - typical distribution of VTTS (from Dutch SP research)

3. A number of pricing options were examined, including:
   - All 'free' links (NT)
   - 'First-best' pricing on all links (FB), i.e. pricing at SRMC, to maximise economic welfare
   - 'Second-best' pricing on one of two parallel links, the other being 'free' (SBPL)
   - 'Revenue-maximising' pricing on one of two parallel links, the other being 'free' (PPL)

4. The assessment compared toll levels, traffic volumes, toll revenues, travel times and social welfare across the different options. Social welfare for the first-best pricing option (FB) was set as 100, relative to social welfare for the 'free' situation (NT) as zero.

5. Key results included:
   - SBPL **–** This option involved toll levels less than half those under PPL, or under FB. Net welfare was only 23% of that under FB (but greater than that under NT).
   - PPL – This option involved a toll level similar to that under FB, but considerably above that under SBPL. Net welfare was considerable less than under SBPL, and below that for NT.
   - If a single homogeneous VTTS were assumed rather than the distribution adopted, the net welfare result for SBPL would be considerably worse: the 23% above would reduce to 2.5%, i.e. very close that that for NT.

6. The main findings of most relevance here (to a situation with a priced route in parallel with a free route) may be summarised as follows:
   - In social welfare terms:
     - second-best welfare-maximising ('public') pricing is very much inferior to first-best pricing,

  - revenue-maximising ('private') pricing is substantially inferior to second-best pricing, and inferior to 'free' routes .

- In terms of toll levels and revenues:
  - second-best tolls are less than half the level of revenue-maximising tolls, and revenues rather more than half,
  - both second-best and revenue-maximising toll revenues are only a small fraction of first best toll revenues.

- In the specification and evaluation of second-best policies, it is critical to allow for the real-world distribution of VTTS, rather than a single VTTS value (which would under-state the welfare benefits).

7. The critical conclusions in terms of selected toll road policies are:
   (i) Pricing of selected links is very much inferior to first-best pricing of the whole network, both in welfare terms and in revenue-raising terms. In welfare terms it may be inferior to an all-free network.
   (ii) If a selected link pricing policy is being pursued, then 'public' (second best) pricing is considerably superior to private (revenue-maximising) pricing in welfare terms. However, 'public' pricing will result in toll and revenue levels in the order of half those for 'private' pricing. There is a clear trade-off between welfare and revenues.

B2. The Value of 'Value Pricing' of Roads – Second-best Pricing and Product Differentiation

Reference: Small, K.A., Yan, J. [March] 2000. University of California at Irvine. 27pp.

1. Small & Yan's paper examines optimum pricing policies and their impacts for situations in which travellers can choose between a free but congested road and an alternative priced road. It focuses particularly on assessing the impacts of heterogeneity in VTTS on the evaluation, assuming two different user groups.

2. Five alternative pricing policies are considered:
   - No tolls (NT)
   - First best (FB), i.e. maximising welfare, involving marginal cost pricing
   - Second best (SB), i.e. maximising welfare subject to the constraint of no tolls on one road
   - Profit maximising (PM), i.e. maximising revenues on one road, with no tolls on the other road
   - Third best (TB), i.e. as SB but with an additional minimum level of service constraint on the priced road.

3. In the case of homogeneous VTTS (one single value for all users), it is found that:
   - For SB, the optimum toll (one road) is around only 20% of the FB toll (both roads), and the welfare gains (relative to NT) are only between 5% and 10% of the FB welfare gains.
   - For PM, the optimum toll is around four times that for SB (but still below that for FB); and there is a net welfare loss (relative to NT).

4. When more heterogeneity is assumed:
   - The welfare gains from all differential pricing policies increase (relative to the homogeneous case).
   - The welfare benefits of the SB and PM policies improve as proportions of the FB benefits, e.g. the SB welfare benefit increased from 6% to 28% of FB.
   - The FB policy continues to produce a welfare loss (relative to NT).

5. The main conclusions of the paper relevant to the present context are:
   - *Our results demonstrate the importance of heterogeneity in value of time for evaluating congestion policies that offer pricing as an option. Generally, the existence of heterogeneity favours such policies because product differentiation then offers a greater advantage: those with high values of time reap more benefits from the high-priced option, while those with low values of time find it all the more important not to be subjected to policies aimed at the average user.*

- *Nevertheless…….insisting that one of the products be free imposes quite a large penalty (except when heterogeneity is extreme). In our base scenario for moderate amounts of heterogeneity, a second-best one-route pricing policy achieves only one-sixth to one-third the possible welfare gains of first-best pricing, and uses a much smaller toll.*

- *Even more alarming, a revenue-maximising policy sets the price far higher, and achieves benefits far lower, than second-best pricing. This is true no matter what the heterogeneity. In the majority of cases, the overall benefits from pricing are negative for these policies.*

These findings of Small & Yan (2000) are not inconsistent with those of Verhoef & Small (2004).

B3. Second-best Congestion Pricing in General Networks

Reference: Verhoef, E.T. 2000. Tinbergin Institute *Discussion Paper TI 2000-084/3.* 25pp.

1. Verhoef's paper considers the determination of second-best prices for situations where not all links of a congested network can be tolled. It generalises from earlier work on this topic and develops an algorithm for deriving second-best tolls. It then applies this in a simulation model to study its performance for various archetype pricing schemes (e.g. parking charges, toll ring, first-best pricing) applied to a simplified network.

2. Key findings relevant to the current context include:
   - Second-best pricing on individual links (with competing links being free) results in welfare improvements only a small fraction (between 1% and 13%, in different cases) of the improvements associated with first-best pricing.
   - This result is based on an assumed single VTTS. Other work indicates that a more realistic assumed heterogeneous function would result in significantly higher welfare benefits for second-best pricing, but these would still be only a small fraction of those from first-best pricing.
   - By contrast, several other policies assessed (e.g. parking charges, area licences, toll rings) result in welfare improvements not much less than the improvements from first-best pricing.

3. The paper concludes by stating that:

   The situation model confirmed earlier findings that parallel route pricing schemes constitute a relatively inefficient type of second-best pricing.

4. The findings of this paper are not inconsistent with those of Verhoef & Small (2004).

B4. Multi-period Congestion Pricing Models and Efficient Tolls in Urban Road Systems

Reference: Liu, N.L. [December] 2004. *Review of Network Economics 3(4):* 381-391.

1. Liu's paper reviews recent advances in multi-period congestion pricing models in urban road systems. It presents mathematical formulations of various congestion pricing problems for two time periods (peak, off-peak) and for a simple road network. Procedures are developed for conducting a simulation study of the peak and off-peak congestion pricing models to examine congestion tolls and their effects on traffic allocations and social welfare. Major findings from the analysis results are presented.

2. Three pricing policies were considered:
   - NT: No tolls on either of the two routes.
   - FB: Optimum (congestion-related) tolls on both routes in both time periods. Optimum tolls are set equal to marginal (congestion) costs.
   - SB: Tolls on one route, not on the other. The optimum toll in each period is equal to the marginal (congestion) cost plus two adjustment terms.

3. Simulation procedures were adopted to find price solutions for the three policy options, using Newton's method to solve the non-linear equations. Appropriate cost and demand functions were specified: a single VTTS was used. Output results for each option include: traffic volumes by route/period; (congestion) tolls and trip prices; social welfare and welfare changes.

4. Main findings in Liu's paper were as follows:
   - *The second-best congestion pricing policy has three major impacts on the traffic volume allocations: (1) the diversion of the peak period traffic to the free route, (2) the shift of the peak period traffic to the off-peak period, and (3) the reduction in total traffic volumes. However, the second-best policy is less effective than the first-best policy in reallocating traffic volumes primarily because the FB scheme allows the tolls on both routes.*
   - *The second–best tolls differ markedly from the first-best tolls. In the peak period, the second-best tolls are smaller than the first-best tolls. For example, the peak period toll on the toll route (in case 2) is $1.08 per mile in model FB versus $0.48 per mile in model SB. In the off-peak period, for most cases, the second-best tolls are smaller than the first-best in some cases. (In one case the SB toll in the off-peak period is negative.)*
   - *The welfare property of the second-best congestion pricing policy is less desirable than the first-best policy. Although both the second-best and the first-best policies have social welfare gains against the no-toll policy, the welfare gains yielded by the second-best are less than half of the welfare gains by the first-best scheme (45.8%, 45.3%, 19% and 11.4% for the four cases tested). Therefore, the failure*

to impose a congestion toll on a major part of the network may result in a loss of the potential welfare gains.

- Various sensitivity tests showed welfare gains under the SB policy in the range one-third to one-half of those for the FB policy.

5. In conclusion the paper notes that research could usefully be extended in the following areas:
   - Extension to multi-periods and alternative modes (car v transit).
   - Extension from a two-route network to a general network (as per the work of Verhoef).
   - More general formulation of demand functions.
   - Extension to heterogeneous VTTS function (see Verhoef & Small 2004).

6. The results are not inconsistent with those of Verhoef & Small (2004).

B5. The Economics of a Single Toll Road in a Toll-free Environment

Reference: Gronau, R. 1999. *Journal of Transport Economics & Policy 33(2):* 163-172.

1. Gronau's paper examines the welfare implications of a toll on one road when alternative roads are free, both in the short-run (taking capacity as fixed) and in the long-run (allowing capacity to vary). It involves an economic/mathematical appraisal but without quantitative modelling.

2. The paper summarises its findings as follows:
   - *The study emphasis the conflicting roles of the toll: it reduced total traffic, thus reducing the gap between the price paid by travellers and marginal social costs, but diverts traffic to the free (and usually inferior) road. This conflict may give rise to a situation in which no toll is preferable to a single toll. The probability of the existence of such a situation increases, the less congested the toll road, the more congested the free road, and the less sensitive total demand to price.*
   - *Even a socially desirable single toll will reflect this conflict. At the optimum the price usually falls short of marginal social costs, the free road is over-utilised, and the toll road is under-utilised.*
   - *A profit-maximising toll agency charges a toll that is higher than optimal, thus exacerbating the congestion problem of the free road. More importantly, the agency charges higher tolls the smaller the elasticity of travel demand and the more congested the free road – in sharp contrast with the policy adopted by a welfare-maximising agency.*

3. The paper concludes by stating:

   Adding all these factors to the welfare implications discussed in the paper indicates that caution should be exercised before deciding on the use of this policy tool to combat congestion.

4. The findings of this paper are not inconsistent with those of Verhoef & Small (2004).

B6. Long-run Effects of Partial Tolling Schemes

Reference: Douville, E.L. [December] 2004. *Review of Network Economics 3(4):* 392-400.

1. Douville's paper makes estimates of the effects of various partial tolling schemes in a long-run setting where road capacities are optimised. For various tolling schemes it examines welfare impacts relative to the first best (pricing and investment) situation. It also examines toll levels, optimal road capacities, levels of road traffic and operating conditions (average travel speeds etc.).

2. The model used is a two-road, two-period (peak/off-peak) model of commuting trips. A simplified traffic congestion model was used, and cost parameters selected to represent a highly congested situation.

3. Options considered were:
   - No tolls (base case),
   - Optimal tolls on both roads in both periods ('first best'),
   - Tolls in both periods on one road only,
   - Tolls on both roads in peak only,
   - Tolls on both roads in off-peak only.

   All analyses involved optimising the tolls and the road capacities to maximise net benefits.

4. The results of most relevance in the present context (i.e. focusing on the relative performance of the first three of these options) include:
   - The 'first best' option gives the highest benefits, set at 100 relative to the 'no tolls' option (=zero).
   - The 'one-road' toll option provides only 35% of the benefits of the 'first best' option.
   - For the 'one-road' option, the optimum peak toll is 60% of the first-best peak toll; and the optimum off-peak toll is 24% of the first-best peak toll.
   - The 'one-road' option largely shifts travel between the two routes, with little shifting between time periods.
   - Tolling reduces the optimum road capacity in every case. The first-best road capacity is 83% of the no toll optimum level; while the overall capacity in the 'one-road' system is 94% of the no toll level.

5. These results are not inconsistent with those of Verhoef & Small (2004) for the short-run (constant capacity) case.

B7. Efficient Congestion Tolls in the Presence of Unpriced Congestion: A Case with Non-identical Road Users

Reference: Sapkota, V. Paper to *23rd ATRF:* 773-787. Australian Transport Research Forum, Perth, Sept/Oct 1999)

1. Sapkota's paper applies a deterministic user–equilibrium route choice model to derive the socially-optimal tolls in the context of heterogeneous road users (having a range of VTTS), under three pricing regimes: no pricing, first-best pricing (all roads subject to pricing) and second-best pricing (only selected roads priced). Modelling was undertaken for a simple two-route network and the general network case. The appraisal also examined the impacts of the policies on different income/value of time groups.

2. Key findings include:
   - Toll charges and revenues. Second-best tolls and toll revenues are between a quarter and half of first-best levels. The optimal tolls are lowest for situations with a high proportion of low-income users.
   - Welfare levels. Second-best pricing results in welfare gains (relative to no pricing) are only around one-third of those from first-best pricing.
   - Private costs. First-best pricing results in substantial increases in user private costs (relative to no pricing), in the order of 20% - 30%, with the greatest increases applying to low income users. Under second-best, the increase in private costs is less than one-third of the first-best increases, assuming identical users. However, with non-identical users, some groups have lower travel costs, but low income users are the greatest losers.
   - An important conclusion is that it is highly desirable to allow for the distribution of VTTS (income) values in order to provide better estimates of optimal second-best tolls and of their distributional impacts.
   - These results are not inconsistent with those of Verhoef & Small (2004).

B8. Which Consumers Benefit from Congestion Tolls

Reference: Glazer, A., Niskanen, E. [January] 2000. *Journal of Transport Economics & Policy 34(1):* 43-54.

1. Glazer & Niskanen's paper examines the effects of tolls on one of two modes (routes) on consumer surplus, as a means of looking at likely public acceptability of different pricing policies.

2. The main conclusions of some relevance here include:
   - In the short run, any toll on the slower (more congested) of the two routes will reduce consumer surplus.
   - A toll on the faster route may increase aggregate consumer welfare, and will tend to raise revenue from more affluent users.
   - Ironically, such a toll will further increase congestion on the slower route, and may increase overall average travel times.

3. Note that these conclusions relate to consumer surplus rather than overall economic welfare: conclusions may differ if the toll income generated is recycled to users.

4. These results are only of marginal relevance in the present study context.

B9. Value Pricing: A Possible First Step Towards General Road Pricing Even in Germany

Reference: Englmann, F.C. 2004 [unpaged].

1. Englmann's paper addresses the theoretical and acceptability issues associated with general road (congestion) pricing; examines the case for 'value pricing' (tolling of new capacity only) and some practical examples of its application; and draws conclusions on the potential application of 'value pricing', focusing on motorways in Germany.

2. Its conclusions are as follows:
   - *Even if road pricing is well established in theory it can usually only be realised in the political process of democracies if at least one of the following three conditions is fulfilled: (i) the level of congestion is regarded as unbearable and there exists an attractive alternative mode (like public transport in the City of London); (ii) construction of new roads or lanes for which untolled alternatives exist; (iii) high share of foreign transiting vehicles, especially heavy lorries. The reason for the political difficulties is the reduction of consumer surplus of road users if existing roads are tolled. If, due to a high car availability, road users are the majority of VTTSers, road pricing of existing roads becomes almost impossibly in democracies. Hence, value pricing which just tolls newly built roads or lanes, and hence does not reduce consumer surplus, is the only way to introduce road pricing for private cars at all in order to promote economic welfare.*
   - *Hence, this type of road pricing should be seriously considered for newly built motorways, especially in West Germany. However, as second-best tolls are considerably lower than first-best tolls, value priced roads should not be necessarily owned and operated by private toll revenue maximising firms, as this may lead to a trade-off between economic welfare and financial viability. Concurrently, from the point of view of economic welfare, it does not make sense to reach a high level of service on the toll road by imposing tolls exceeding second-best tolls. This might lead to welfare losses compared to the no toll situation. The welfare effects of value pricing are a question of dosage. In the short to medium run, this dosage should not be made more difficult by involving private investors, who may even hinder further investment in road infrastructure (as has been shown by the example of SR 91 in Orange County).*

B10. Private Sector Involvement in Infrastructure Projects

Reference: Quiggin, J. 1996. *Australian Economic Review 96(1):* 51-64.

1. This paper examines the case for and against private provision of infrastructure, with particular emphasis on the allocation of systematic and idiosyncratic risk. One part of it addresses ownership and pricing issues relating to toll-financed road projects.

2. Its commentary on these issues is as follows:

   - *Toll roads are commonly seen as a category of self-financing project ideally suited for private provision. However, toll roads fail the condition set out above that the project should not involve externalities…..To sum up, because roads are associated with both positive and negative externalities, the ability of a road project to generate sufficient toll revenue to finance its construction is neither necessary nor sufficient to show that the project yields net social benefits.*

   - *It is useful to compare toll financing of individual projects with financing through general charges on all road users, such as petrol taxes and registration fees. Users of a toll road will be subject both to the toll and to the general taxes so that the implicit price for use of the toll road is higher than that for roads in general. Such an outcome will be desirable if, and only if, the negative externalities associated with congestion, pollution, crashes and so on are greater for the roads on which tolls are imposed than for roads in general. This may be the case for bridges, where tolls may be justified as a congestion tax.*

   - *In most cases, however, the negative externalities associated with newly constructed roads, those normally considered for toll financing, are likely to be less than the negative externalities associated with roads in general. Newly constructed roads are likely to be less congested, and further away from built up areas, and, therefore, to generate smaller negative externalities than old roads. In this case, the pricing mechanism itself may reduce the benefits of the project. Tolls on new roads divert traffic onto old, toll-free roads, leading to worse congestion and more accidents. From an efficiency viewpoint, if tolls must be imposed, it would be better to impose them on congested roads regardless of their date of construction or their nominal ownership. In the absence of a general system of road pricing, isolated tolls on new roads will, in general, be inferior to a general system of user charging through fuel taxes and registration fees.*

   - *The traffic diverting effects of toll-financing will reduce the net benefits of road projects, and the toll will fail to capture all of the benefits to road users. Because of these two effects, toll finance will provide sufficient revenue to finance construction only in cases where the benefits of new toll roads greatly exceed the costs. In all other cases, some form of subsidy will be required.*

This may be either a direct public subsidy, a guarantee of debt, or a provision by which the private contractor is allowed to levy tolls on existing roads previously constructed with public funds (as with the Sydney Harbour Tunnel, the M4 Motorway in Eastern Sydney, and the proposed expansion of Tullamarine freeway). In addition, private promoters have not, in general, been required to pay the acquisition costs of land.

- *In summary, toll financing is unlikely to provide sufficient revenue to fund road projects. Because some form of subsidy is usually required, and because road projects involve negative as well as positive externalities, the profitability of a project to its promoters bears little relationship to the question of whether its social benefits exceed its costs. The self-financing rationale, is, therefore, not applicable to road projects in most cases.*

B11. Welfare and Profit Divergence for a Tolled Link in a Road Network

Reference: Mills, G. [May] 1995. *Journal of Transport Economics & Policy 29:* 137-146.

1. Mills' paper examines two claims often explicit or implicit in discussions about the private provision of roads:
   - if a new road is profitable, then it must increase net welfare (relative to a do-nothing alternative);
   - if a new road adds to net welfare, it must be able to be provided profitably.
2. Its most relevant conclusion on the first claim is as follows:

   Where a proposed link is parallel to an existing road which remains available at the same toll (maybe zero), profitability does not ensure that the link will add to welfare; however, an adverse welfare result can occur only if, on the existing link, the toll is greater than the marginal cost of road use.

Appendix C:

Current New Zealand Tolling Policies

C1: Alternative Methods of Funding Future State Highway Projects

C2: Finance and Toll Projects – Implementation Guide

C3: Project Evaluation Manual

C1. Alternative Methods of Funding Future State Highway Projects

Reference: Transit NZ. 2003a. Alternative Methods of Funding Future State Highway Projects. Draft, August 2003.

C1.1 Introduction

This document (Transit NZ 2003a) is the first of three Transit/Transfund publications on alternative funding and methods of project delivery. It explains how the new sources of funding potentially available to Transit NZ as a result of the LTMA will fit within the existing National Land Transport Fund (NLTF) arrangements: these sources include the introduction of tolls.

C1.2 Requirements for Establishing Tolling Scheme (Section 2.2)

This section of the document sets out the requirements that the Minister of Transport has to have regard to before recommending an Order in Council, under the LTMA. It notes that toll schemes can only be applied to the funding of *"new road infrastructure, and related and incidental purposes".*

C1.3 Advantages and Disadvantages of Tolling Schemes (Section 5.2)

This section of the document notes that *"Funding repaid from user tolls is the only genuine alternative that increases funding levels over time. It is therefore the only alternative that allows more projects to be built."*

It summarises the main advantages and disadvantages of road tolling as follows:

Advantages:

- *As additional funding is provided, more projects can be built.*
- *Higher quality infrastructure is made available to those who wish to pay for it.*
- *They can be used to manage traffic congestion by discouraging use at peak times and encouraging a spread of usage throughout the day.*

Disadvantages:

- *The toll is an additional levy on users (on top of fuel taxes or Road User charges already paid).*
- *Unless a network approach to tolling is adopted, tolling can be a greater hardship on some communities while giving an unfair advantage to others who don't have to pay tolls.*

C1.4 Toll Coarse Screening Process (Section 6.3)

C1.4.1 Stage 1 Screening

This stage involves reviewing whether candidate projects meet the Land Transport Management Act (LTMA 2003) requirements, including:

- a feasible alternative road exists,
- does not involve tolling of existing infrastructure.

C1.4.2 Stage 2 Screening

This stage involves screening candidate projects on the following aspects:

- **Project size**. Low-cost projects are generally not favoured.
- **Traffic volume**. Traffic volumes (on an untolled basis) of less than 1500 vpd (vehicles per day) are not favoured, as toll collection costs would be unlikely to be covered by toll revenues.
- **Project economics**. The usual requirement is that net toll revenues (after deduction of operation/maintenance costs of the road and of tolling mechanisms) would contribute more than 10% of the debt repayments.

A number of other issues for consideration are also listed.

C1.5 Issues Arising from Tolling (Section 6.4)

This section discusses a number of issues that will need to be addressed in the implementation of toll proposals:

- Constraints on transport policy
- Electronic toll payment methods
- Toll equity issues
- Compatibility of toll systems

C1.6 Programming of Projects (Section 8.2)

This section notes that Transit will programme alternatively funded projects according to the following approaches:

1. *If the revenues from tolls or other sources fully cover all costs then those projects will be advanced in the programme to their earliest possible start date: these projects will not require NLTP funding.*
2. *If revenues from tolls or other sources cover the debt servicing costs incurred through borrowing to advance a project, then those projects will be advanced in the programme to their earliest possible start date: these projects will require NLTP funding to be committed at the traditional programmed date.*
3. *If revenues from tolls or other sources do not cover the debt servicing costs of advancing a project, then no programming change will be made unless the project qualifies for further exploration under Transfund's Developing Funding Partnerships Policy.*

This section notes that these approaches result in there being no net impact on the NLTP in terms of funding timing or allocation for alternatively funded projects.

C2. Finance and Toll Projects – Implementation Guide

Reference: Transit NZ. 2003b. Finance and Toll Projects – Implementation Guide. Draft, August 2003.

C2.1 Introduction

This Guide (Transit NZ 2003b) provides guidance for implementing alternatively funded state highway projects using concession agreements and tolling schemes as provided for under the LTMA. It provides a step-by-step guide to implementing candidate projects through an alternative funding method.

C2.2 Pre-Screening for Tolling Suitability – Traffic and Toll Modelling (Section 3.2)

The pre-screening process is intended to establish the feasibility of developing candidate projects as potential tolled projects. It first involves traffic and toll modelling, which is then used as an input to financial modelling.

At this pre-screening stage, the traffic/toll modelling involves a simplified desktop approach, using an existing traffic model or an assignment algorithm, without detailed traffic or SP surveys.

Points made in regard to this traffic/toll modelling include:

- Modelling should be based on revenue-maximising tolls.
- Values of time should be based on the standard PEM values.
- Diversion factors should be derived based on a given toll level and value of time, and on the estimated time and distance savings.

C2.3 Developing a Toll Model (Section 6.2)

This section outlines the key requirements for the traffic/toll model at the full assessment stage. It notes that models required for toll scheme assessment require a different focus and generally a higher level of accuracy than 'standard' traffic models.

Table C2.1 sets out the nine components indicated for the modelling process and summarises the key features within each component.

Table C2.1 Components of traffic/toll models.

Component	Key Features
1. Traffic Demand by Market Segment	• Demand should be categorised by market segment. • Segments should be based on behavioural characteristics that will impact on route choice. • Segmentation by vehicle type also desirable (if differential tolls might apply).
2. Network Representation	• Model road network needs to replicate accurately base travel speeds and responses to changes in traffic flows. • Transport policies and projects that could impact on the attractiveness of the toll road need to be tested. • Modelling needs to separately consider periods with differing levels of congestion: use of a single averaged period is unlikely to be satisfactory.
3. Representation of Toll	• Model needs to properly reflect the tolling strategy proposed (and/or to test alternative strategies).
4. Choice Modelling	• Two general approaches can be considered for choice modelling: - matrix-based pre-selection approach, - part of trip assignment stage. • The first approach applies 'diversion curves' at an O-D levels, using network data (time, cost, toll, etc.) and user parameters. It results in the pre-assignment of each user class (by O-D pair) between the tolled and untolled routes, based on the diversion curves. • The second approach is undertaken as part of the normal assignment process, using a multi-class assignment (with each class representing a market segment). • The first of these approaches is generally preferred, as it allows more flexible choice models better replicating observed behaviour. As this approach uses output from a network assignment, an iterative process is required between the choice and assignment models to achieve convergence.
5. Stated Preference Surveys and Value of Time	• User values of time are a key input to the generalised cost equation (combining travel time, VOC and toll charge) used to determine the costs of travel on alternative routes. • SP surveys are the preferred approach to investigating motorists' trade-offs between travel time and toll charges and hence establish values of time. Such surveys need to be disaggregated by market segment and vehicle type. • Analysis of RP data on the use of an existing toll facility may be an alternative to SP surveys in some cases, although there are considerable issues of transferability.
6. Demand Response	• Judgement is required as to whether demand responses other than route choice (e.g. peak spreading, mode choice, trip redistribution) need to be modelled; or whether a fixed trip matrix can be used in both untolled and tolled scenarios.
7. Forecasting	• Long-term forecasting of travel demand is required. • Establishment of accurate base-year conditions is also of critical importance.
8. Revenue Sensitivity and Maximising	• Assessment of the untolled scenario should be the starting point for the appraisals. • A number of 'optimisation' tests should be undertaken: these may include revenue-maximisation, maximising traffic diversion from sensitive areas, and level of service optimisation.
9. Revenue Annualisation	• Process involves the aggregation of revenue estimates and other values from the specific modelled time periods to daily and annual results. • Caution is needed in this process, to account properly for all non-modelled periods (which may have different values of time and hence diversion rates to the modelled periods).

C3. Project Evaluation Manual

Reference: Transfund NZ. 1997. Project Evaluation Manual. *Manual PFM2*, May 1997 (as updated, after 2004 by Land Transport NZ).

This Manual (Transfund 1997 and updates by Land Transport NZ) (Section 3.11) includes a short section on issues associated with the economic appraisal of toll projects. The main points made that are relevant here are:

- Economic evaluations should be undertaken with and without tolls.
- In cases where the facility is privately financed, with tolls being paid to the concessionaire, the tolls should be treated as resource costs other than transfer payments. (By extension, for publicly funded toll schemes, the tolls are to be treated as transfer payments.)
- *"When calculating the B/C ratio, tolls should be considered as disbenefits".*
- For evaluation of privately financed (PPP) schemes, the relevant costs are the initial government costs of the project; while the (net) benefits are gross benefits less the toll payments (all in PV terms).

Appendix D:

Tolling Case Studies – New Zealand

D1: Alpurt B2 Project

D2: Transmission Gully Motorway

D3: Tauranga Harbour Link

D4: Other Tauranga Toll Roads

D1. ALPURT B2 Project

D1.1 References

1. Beca. 2004a. ALPURT B2 Economic Evaluation Report. Report to Transit NZ, September 2004.

2. Beca. 2004b. ALPURT B2 - Update of Economic Evaluation. Letter to Transit NZ, 13 September 2004.

3. Hyder Consulting. 2004. Traffic & Toll Modeller Contract – Model Validation and Forecasting Report: Northern Motorway Extension. Final Report, January 2004.

4. New Zealand Herald articles, 2004:
   (a) 3/12/04
   (b) 13/12/04
   (c) 21/12/04

5. The Urban Transport Institute (TUTI). 2004. Stated Preference Surveys to Estimate Values of Time for New Zealand Toll Roads. *TUTI Report 27-2004* to Transit NZ, March 2004.

6. Transit NZ/Rodney DC. Northern Motorway Extension – Supporting Report for Transfund Allocation Process Assessment. *Final Report, Version 2.0.*

7. Transit NZ. 2004. The Case for ALPURT B2 as a Toll Road.

8. Website: www.transit.govt.nz/alpurt_b2/

D1.2 Overview

D1.2.1 The Project

- Part of the Northern Motorway Extension, involving a bypass of Orewa.
- 7.5km, 4-lane dual carriageway motorway.
- Approx construction cost $320M (escalated figure at December 2004 quoted as $365M, Reference 4(c)).

D1.2.2 Scheme Development

- Scheme being progressed (design and build) by the Northern Gateway Alliance, an alliance between Transit, consultants and contractors.
- Transit has agreed that scheme should proceed as a toll road – likely to be first New Zealand toll road involving electronic toll collection.
- Start of construction made in December 2004.
- However, the tolling system to be adopted is still under consideration by a Government working party, which was expected to report by end of March 2005 (Reference 4(b)).

D1.3 Value of Time Survey

An SP survey of potential users of the ALPURT scheme was undertaken in February/March 2004 to investigate their time v cost trade-offs and hence their values of travel time savings (VTTS) associated with the use of a toll road. This survey and results are described in Reference 5.

Key features of the survey were:

- Adopted the 'semi-adaptive boundary-value SP survey method', administered by computer-assisted telephone interviewing (CATI).
- Target population consisted of drivers who had made a trip through the Orewa area in the past month. These were initially identified through an observational survey of number plates of vehicles travelling through the area, which were then matched with Motor Vehicle Registration records and hence vehicle owner details were found.
- The final sample involved 402 (vehicle driver) respondents, split into 4 market segments by trip type:
  - Home-based work/education,
  - Home-based other,
  - Non-home based,
  - Commercial vehicle.

The survey analysis established a VTTS ($/hour) and a toll road constant, TRC ($), for each respondent, and hence derived the distributions of these parameters for each market segment.

Table D1.1 Summary of SP survey results.

Trip Purpose	Sample Size	Value of Time Savings ($/h)			Toll Road Constant ($)		
		Mean Value	Std Dev	Std Dev/ Mean	Mean Value	Std Dev	Std Dev/ Mean
HBWE	100	13.96	19.42	1.39	–0.16	1.31	8.2
HBO	103	10.51	13.97	1.33	–0.10	1.10	11.0
NHB	100	14.15	22.65	1.60	–0.42	1.80	4.3
CV	99	14.77	20.89	1.41	–0.22	1.19	5.4
Total	**402**	**13.33**	**19.47**	**1.46**	**–0.22**	**1.38**	**6.3**

HBWE Home-based work/education
HBO Home-based other
NHB Non-home based
CV Commercial vehicle

Table D1.1 provides an overview of the results for each market segment. Key findings of most relevance here, from these results and other analyses in the report include:

- The wide distribution of VTTS: the coefficient of variation (standard deviation: mean) is in the range 1.3 to 1.6 for the four market segments.
- The 90% confidence intervals on the mean VTTS for each segment are around 23% of the mean, with the overall confidence interval being around 12% of the mean.
- All the TRC values are small and negative (i.e. biased against use of the toll road). However the mean values are not significantly different from zero.

- VTTS tends to increase with income. For medium/higher income groups (personal income over c.$30,000 pa), VTTS averages around 40% of hourly income (consistent with results from other studies internationally); whereas for lower income groups, average VTTS appears to be greater than 100% of the hourly wage rate.

The features of these results that are perhaps of greatest significance for New Zealand toll road studies are:

- The wide distribution of VTTS: this has substantial implications for both traffic modelling and economic evaluation of tolling schemes.
- The apparently very low toll road constant in this case (this contrasts with a much higher value obtained from the 1999 Transmission Gully market research). The low value may in part reflect the way the questions were posed, with respondents perhaps not taking sufficient account of congestion and unreliability of using the 'free' route.

We would also note that the survey questions asked respondents to choose *"between a free road and a toll road which took Y minutes less and cost C"*; but no mention was made of any difference in distance (and hence VOC) between the two choices. It is thus unclear whether respondents would assume that there would be no difference in distance; or whether, knowing of the ALPURT scheme, they would allow for their estimate of the difference in distance for this scheme (which is quite substantial). This appears a significant point to be addressed in the traffic modelling for the scheme.

Another significant issue noted relates to the time savings valuations for vehicle passengers. The survey covered car drivers only, with an apparent emphasis on establishing their individual values of time savings rather than the value of time savings for all their vehicle occupants in total. But it would be expected that vehicle passengers would also value time savings, although most likely at different rates from drivers (they do not face the stress of driving, and are likely to have a very different age and income distribution from drivers). Thus, it appears that the survey provides no information on the valuation of travel time savings by passengers, or by multiple-occupancy vehicles: it is this latter information that is most relevant to modelling travel behaviour and estimating road user benefits.

D1.4 Traffic Model Validation and Revenue Forecasting

On behalf of Transit NZ, Hyder Consulting developed demand (patronage) and revenue forecasts for the ALPURT B2 toll road scheme: this modelling process is described in a comprehensive report (Reference 3). We have briefly reviewed this report, but have not attempted a detailed critique (only some aspects of the model have, in any event, been used in the economic evaluation).

We would comment on a few relevant aspects, as follows:

- The report notes (p. 11) that the uncertainty on the value of time (VTTS) is one of the key risk factors in forecasting toll road usage. The weight of international evidence is that real VTTS increase over time (on account of increasing real

incomes). However the report adopts a constant 'diversion rate' for all years, despite some (brief) discussion of reasons why this would be expected to decline over time. Given the potential importance of this aspect, we would have expected a more in-depth assessment, desirably accompanied by sensitivity tests.

- The report does not make it clear whether the various toll revenue estimates given are inclusive/exclusive of GST.
- The traffic modelling appears to be based directly on the mean values of time derived (by trip purpose) in the SP survey. As noted above, these values appear to relate to vehicle drivers only; whereas the values required for traffic modelling should relate to the total for all occupants.

D1.5 Traffic Modelling and Economic Evaluation

As input to its economic evaluation work (References 1, 2), Beca developed and applied a preliminary traffic model, not directly using either the SP VTTS survey results or the Hyder traffic model and forecasts (above). The following summarises and comments on Beca's preliminary modelling, particularly in regard to its application to the economic evaluation.

D1.5.1 Traffic Modelling Methodology

Base Modelling/Forecasting Methodology (Reference 1, Section 5)

Key features of the modelling/forecasting methodology for all options include:

- *Route choice* (untolled) – assumptions made for each of 4 main movements as to whether or not they would use the new route.
- *Travel times*
  - used bottleneck model plus speed/flow functions,
  - calibrated model against observed travel times for weekdays (3 periods), Saturdays, Sundays,
  - applied model for 4 periods: Mon-Thurs 1200, Friday 1700, Saturday 1400, Sunday 1600.
- *Traffic growth* – linear growth assumptions, based on historic growth trends.

Toll Diversion (Reference 1, Section 5.8)

Key features of the modelling of the effects of the toll charges on traffic movements are as follows:

- It is stated that *"For the purposes of this economic evaluation, a 20% diversion due to the toll was assumed".*
- It is noted that this same assumption was adopted for all periods and all forecast years.
- To support this assumption, the report states:

  In order to determine a suitable toll diversion rate to be adopted for the Northern Motorway Extension project, diversion rates forecast by major models in Melbourne and Sydney have been reviewed. While confidentiality requirements prevent direct reporting of these forecasts, Hyder has advised that

> *typical diversion rates for major urban toll roads is typically around 20% to 30%. The lower levels of diversion typically occur in areas where route choice is limited, while the higher diversion levels occur where there are multiple alternative routes and the value proposition is less.*
>
> *While this value may appear low, giving a high capture rate on the toll road, it is consistent with projects in Australia and reflects the value proposition offered by the Northern Motorway Extension.*

D1.5.2 Comments on Toll Modelling Aspects

The evaluation assumes that, of the total traffic that would use the new scheme as a free route, 20% would transfer to alternative routes if the specified toll was imposed. This assumption has been applied to all time periods, all years, and (implicitly) all trip purposes/vehicle types.

This assumption may or may not be reasonable as an average diversion rate. It is certainly simplistic. The report suggests that part of the reason for its adoption is pragmatic, because of the limitations of the bottleneck model:

> *The bottleneck model uses a single value for the level of diversion from the toll road to assess the benefit stream. The model adopts the same level of diversion across the different forecast years, as it (is not) cannot take into account changing demand characteristics and the resulting changes in value of time over time as discussed above.*

We have some reservations as to whether this is a valid reason for adopting the simplistic assumption made.

The report itself notes that toll diversion rates are likely to vary with a number of factors:

- Traffic volumes,
- Commercial v other vehicles,
- Future trends in congestion and in (real) value of time,
- User values of time – high v low value users.

We agree with this comment. We assume (see above) that further traffic modelling work will be undertaken, making use of the SP VTTS survey results.

D1.5.3 Toll Charges

All the economic analyses (refer below) are based on a toll of $1.80 ($3.60 for HCVs).

The Transit report comments as follows on the issues in setting toll charges (Reference 6, Section 8.25):

> *8.25 As part of considering the road as a toll road, Transit has, and will continue to, consider the rate at which the toll would need to be set to maximise the efficiency of the route, and sustain the decongestion and other community benefits over time. While yet to be formally considered, this assessment is expected to include consideration of whether there might be an opportunity*

to vary the toll to assist in managing peak demand. In deciding on toll tariffs, consideration has to be given to the balance between:

- ***Achieving optimal network utilisation*** *– where a toll is low enough to encourage people to use the toll road, but sufficient to meet the costs of building and operating the toll road; and*
- ***Revenue maximisation*** *– setting the toll at a level that will pay off the toll road sooner, but which could increase the level of traffic diversion. The lower the toll tariff, the longer tolls will need to be charged to repay the debt used to finance ALPURT B2's construction.*

8.26 A range of toll tariff options has been modelled to forecast the likely traffic volumes at various points on the network and expected revenues. From that analysis, two possible toll tariff options have been identified:

- ***Option 1: $1.80 toll tariff:*** *Transit's preferred toll option is the $1.80 toll in each direction (CPI indexed to opening day). This would optimise the overall use of the network – including the toll road and the alternative routes – while still ensuring that the project will be financially viable. This is the lowest toll tariff option possible to comply with the advancement criteria for toll projects approved by Transit's Board and outlined in the Alternative Methods of Funding Future State Highway Projects Policy.*
- ***Option 2: $2.20 toll tariff.*** *This is the revenue maximising toll. It is not the preferred option as it could discourage use of the road and increase traffic diversion.*

8.27 Toll tariffs are in 2004 dollars and the opening day tariff would be indexed to consumer price movements. Tolls would be charged in both directions of travel on ALPURT B2. Tolls for heavy commercial vehicles (HCVs) would be $3.60.

One implication from this statement is that modelling has been undertaken of how the use of the route would vary with the toll level. We are unclear whether this modelling is based on the Hyder/TUTI SP results, or other sources.

D1.5.4 Economic Evaluation Results and Comments

Table D1.2 sets out Beca's latest (September 2004) economic evaluation results for the scheme, as both a tolled and an untolled scheme, in both cases relative to a 'do minimum' base (References 1, 2). It also shows the key differences between the tolled and untolled schemes.

Table D1.2 Summary of economic evaluation results for ALPURT B2 Project.

All costs and benefits in NZ$M (2004), PV terms (5 year construction, 20 year operation) *All figures relative to a 'Do Minimum' base*			
Item	**Untolled Option**	**Tolled Option**	**Tolled – Untolled**
Capital Costs and Funding:			
Total Capital Costs (undiscounted)	324.6	341.1	16.5
NLTP Funding Requirements: Initial	320	180	
Ongoing		25 (PV)	
Costs:			
Capital	231.8	241.6	
Operation & Maintenance	13.3	27.0	
Total	**245.1**	**268.6**	**+23.5** (+9.6%)
Benefits:			
Travel Time	339.7	326.2	
Congested TT (CRV)	76.3	76.2	
Trip Reliability	10.0	9.5	
Vehicle Op Costs	37.8	32.3	
Crash Costs	36.6	31.1	
CO_2 Costs	1.9	1.6	
Total	**502.3**	**476.9**	**–25.4** (–5.1%)
Revenues:			
Revenue Total	–	**66.3**	**+66.3**
Net Costs	**245.1**	**202.3**	**–42.8** (–17.5%)
Net Benefits	**502.3**	**410.6**	**–91.7** (–18.3%)
NPV	**257.2**	**208.3**	**–48.9** (–19.0%)
BCR:			
On Gross Costs	**2.05**	**1.78**	**–1.08**
On Net Costs (Leveraged)		**2.03**	**+2.14**

Source: Reference 2, p.5.7. Also Reference 6, pp.77-79.

The main findings in relation to these differences (i.e. reflecting the effects of tolling) in PV terms are:

- Both capital costs and recurrent costs increase. Total (discounted) gross costs increase by $23.5M (9.6%).
- Gross benefits (i.e. excluding toll payments) reduce by $25.4M (5.1%).
- Hence NPV reduces by $48.9M (19.0%).
- Total revenue raised by tolls is $66.3M.
- In net terms (i.e. after netting toll revenues off both costs and benefits), net costs are $42.8M (17.5%) lower than under the untolled option and net benefits are $91.7M (18.3%) lower.
- The untolled BCR is 2.05.
- The tolled BCR on gross costs and gross benefits (i.e. the 'unleveraged' BCR) is 1.78, somewhat lower than the untolled BCR; while the BCR on net costs and net benefits (i.e. the 'leveraged' BCR) is 2.03, i.e. virtually unchanged from the untolled figure.

The key implications of these findings appear to be that:

- Tolling raises $66.3M in revenue but reduces the intrinsic worth of the project (as measured by net welfare benefits, or NPV) by $48.9M. (It might be commented

that this indicates the tolling scheme is economically a rather inefficient way of raising revenue.)

- In terms of funding priorities, the leveraged BCR figures provide a priority ranking for use of Transfund's limited funding resources. As the leveraged BCR for the tolled option is almost unchanged from that for the untolled option, this indicates that tolling the scheme should not, per se, result in it being given higher priority for funding (but noting that tolling will reduce the PV net costs by some $43M or 18%).

At this stage, we are unable to comment on the reasonableness of these results: as noted above, we assume further more detailed traffic modelling and economic evaluation work is to be undertaken.

However, two points might be made in terms of the evaluation methodology adopted (additional to traffic modelling issues):

- A fixed trip matrix appears to have been used in all the modelling/evaluation work to date. This simplification may well materially affect both the user benefit and toll revenue estimates.
- The use of average values of time will produce significant distortions in the evaluation results: it is likely to under-state the benefits to those that choose to use the toll road; and to substantially over-state the difference in benefits between the tolled and the untolled options.

Further comment on both these issues is given in the content of the Tauranga Harbour Link scheme (Appendix D3.6 of this report).

D1.6 Toll System Costs

The evaluation adopts the following incremental costs associated with the toll system:

- **Scheme Capital:** $16.5M (Reference 1, Section 8.5.2).
- **Scheme Maintenance and Operation:** $0.60M pa year 1, $0.35M pa subsequent years (Reference 1, Section 8.5.2).
- **Administration:** $0.68M pa in year 1, increasing to $3.30M pa in year 20 (Reference 1, Capital Costs spreadsheet).

This Administration cost is based on an estimate of $0.32 per transaction (Reference 1, Section 4.4). This has been estimated as a unit charge relating to funding of back-office, marketing and customer service functions associated with the proposed national Toll Systems Project (Reference 6, Section 15.10).

D2. Transmission Gully Motorway

D2.1 References

1. Tim Kelly Transportation Planning Ltd. 2004. Transmission Gully Motorway – Evaluation Update. TGM Briefing, 5 July 2004.

2. Tim Kelly Transportation Planning Ltd. 2004. Transmission Gully Motorway – Assessment of Issues: Briefing of Work in Progress. TGM Briefing, 27 May 2004.

3. Tim Kelly Transportation Planning Ltd. 2004. Transmission Gully Motorway: Briefing May 2004. Briefing Note 0504, May 2004.

4. Beca. 2004. Transmission Gully Motorway – Parallel Traffic Modelling. Report to GWRC, June 2004.

5. Deloitte. 2004. Transmission Gully Public Tolled Model. Memo to Robert Jamieson (Beca), 9 July 2004.

6. Beca. 2004. Transmission Gully – Route Security Benefits. Report to GWRC, June 2004.

7. Brown Copeland & Co Ltd. 2004. Additional Economic Benefits from the Transmission Gully Project. Report to GWRC, 26 March 2004.

8. Michelle Rush Consulting Ltd/PLACE Consultants. 2004. Transmission Gully Motorway: Social and Environmental Impact Assessment Report.

9. Tim Kelly Transportation Planning Ltd. 2004. TGM Toll Elasticities. Paper to GW, February 2004.

10. Tim Kelly. 2005. Various email and phone communications, 18/20/21 January 2005.

11. Karen O'Reilly (GWRC). 2005. Phone communication, 21 January 2005.

12. TDG. 1999a. Transmission Gully Project Evaluation. June 1999.

13. TDG. 1999b. Transmission Gully v Coastal Route Economic Comparisons – Final Report. December 1999.

14. PWC. 2004. Transmission Gully Procurement, Financing and Funding. November 2004.

15. Tim Kelly/Clement Fisk. 2000. TGM Benefit/Cost Analysis Summary. December 2000.

16. Tim Kelly Transportation Planning Ltd. 2003. TGM: Coarse Reappraisal of Economic Benefits. May 2003.

17. McDermott Miller Ltd. 1999a. Transmission Gully Community Survey: Report on Household Survey of Regional Residents. Report to WRC, May 1999.

18. McDermott Miller Ltd. 1999b. Transmission Gully Community Survey: Stage II – Face-to-face and Household Telephone Willingness-to-Pay Surveys. Report to WRC, November 1999.

19. Booz Allen & Hamilton. 2001. Development of Benefit Parameter Research Approaches. *Transfund NZ Research Report No. 197*.

D2.2 Overview

D2.2.1 The Project

- SH1 bypass/alternative route, Linden-Mackay's Crossing.
- 24.3 km, 4-lane dual carriageway, motorway standards.
- 'Expected estimate' land/construction costs $830M (2004) – 95%ile estimate $950M (figures exclude tolling infrastructure?) (Reference 1).
- Latest BCR estimates, as in tolled project, are in range 0.5 to 1.1 (Reference 1).

D2.2.2 Scheme Development

- Scheme being progressed between Greater Wellington RC (GWRC) and Transit NZ.
- Subject of extensive studies over the last c.15 years. Key studies that remain relevant include:
  - Community and Willingness-to-pay surveys (1999)
  - Traffic modelling studies (2003-04)
  - Route security benefits study (2004)
  - Additional economic benefits study (2004)
  - Economic evaluation update studies (2003, 2004)
  - Tolling revenue studies (2004)
  - Social and environmental impact studies (2004)
- The scheme is currently subject to further comprehensive review in the context of the GWRC/Transit Western Corridor Study.

D2.3 Traffic Modelling

D2.3.1 'Willingness-to-pay' Surveys

The 1999 'Transmission Gully Community Survey' undertaken by McDermott Miller was designed to gauge (inter alia) *"the likely use of Transmission Gully as a free or toll road"*. Face-to-face surveys (c. 250 respondents) were undertaken to determine WTP tolls to use the TG route, against a range of specified time savings (Reference 18). A critique of the survey methodology and a summary of the results is provided in an earlier Transfund NZ research report (Reference 19).

Key findings of the WTP survey included:

- For 50% use of the TG route, the toll would be approximately $1.90 at zero time savings, $4.10 at 15 mins saving, $6.20 at 30 mins saving, $8.50 at 45 mins savings.
- For zero time savings (all trip purposes), approx. 80% of trips would use TG at zero toll, 46% at $2 toll, 28% at $4 toll, 14% at $8 toll.

The implied average values of time savings (VTTS) for car travel varied by purpose between approximately $6/vehicle hour (shopping) and $12/vehicle hour (business). These results appear generally plausible.

The arguably more surprising result was that 14% of respondents were apparently willing to pay an $8 toll in the case of no time savings. This suggests they were prepared to pay substantial amounts for the perceived increased safety, greater reliability and reduced congestion on the TG route. This finding must be open to some doubts as to its plausibility (see Reference 19 for further discussion).

Our understanding is that subsequent traffic modelling of the project (see below) has been based largely on the results of this WTP survey.

D2.3.2 Main Traffic Modelling (GWRC)

We understand that the main traffic modelling for the scheme was undertaken by GWRC in 2003-04 using a modified version of the regional transportation model (WTSM). While a formal report has not been prepared on this work, our understanding from information available and discussions (Reference 11) with the GWRC staff most involved are (in summary), as follows:

- Initial toll modelling adopted a deterministic approach, based on the assignment process: it used multi-class assignments with each trip purpose assigned separately according to its average VTTS (from the WTP surveys), i.e. the toll level for each purpose was translated into equivalent minutes of travel time for assignment purposes, using the average VTTS for that purpose. It was found that the WTP survey results distribution could not be reasonably reproduced using this approach (as the multi-class assignment method did not reflect a sufficient spread of VTTS). This approach was therefore abandoned.
- Subsequent modelling used a probabilistic (stochastic) approach. From the WTP survey results, a function was defined to give the % of motorists using the toll route for varying values of toll level and time savings. This function was then used to 'reassign' the untolled case traffic volumes (by O-D pair) for a specified toll level: an iterative process was used to derive the equilibrium travel times and traffic volumes.

The GWRC modelling used the full WTSM demand model, thus allowing effects of trip distribution, mode choice and peak spreading to be represented. It was undertaken for forecast years of 2016 and 2026. (Modelling of the untolled TGM, relative to the base case, indicated an increase in daily road trips in the corridor of the order of 15% and a reduction in train trips in the order of 15% (Reference 1)).

This adopted method was found to result in a revenue-maximising toll of approximately $4 (compared with approximately $2 using the initial approach). On this basis, maximum toll revenue was estimated at $10-15M pa in 2016, $15-20M pa in 2026 (Reference 1).

D2.3.3 Parallel Traffic Modelling (Beca)

In 2004, Beca undertook a 'parallel' traffic modelling and evaluation exercise for GWRC, to provide an 'independent' order-of-magnitude check on the quantum of economic benefits and revenue estimated from the GWRC studies.

As compared with the GWRC traffic analyses (above), Beca used:

- A fixed trip matrix
- A 'deterministic' modelling approach, whereby route choice is determined through the assignment process. The generalised cost function used in the assignment (in GC minutes) was expressed as a combination of:
  - Travel time
  - Vehicle operating costs/VTTS
  - Toll charge/VTTS
  - 'Intangible benefits of using the route (mins/km) ∗ distance travelled on route.

The 'intangible benefit' term is effectively the WTP value for use of the route with zero time savings (from the WTP surveys).

An iterative multi-path assignment method was adopted, loading each of eight market segments simultaneously. These market segments and their corresponding average values of time savings were as follows:

Segment	Average VTTS/Hour
Commuter:	
- low VTTS	12.91
- medium VTTS	13.97
- high VTTS	14.96
Home-based other:	
- low VTTS	9.70
- medium VTTS	10.52
- high VTTS	11.28
Business	18.30
HCV	30.00

It is noted that the 'commuter' segment (12.6% of total trips) and 'home-based other' segment (61.8% of total trips) were each divided into three sub-segments based on VTTS distributions derived from the WTP surveys. Assuming the VTTS adopted for each of the three sub-segments represents (in each case), the mean (or perhaps median) values for each third of the distribution, it is notable that the spread of the VTTS values used is very low. For both commuter and HBO segments, the difference between the 'low' and 'high' segment VTTS is about 15% of the 'medium' segment value. By contrast, the results for similar WTP surveys undertaken in 2004 for the PenLink project gave the difference in mean VTTS between 'low' and 'high' third segments as at least twice the mean for the 'medium' segment. It seems implausible that such a difference in distributions could be genuine: we would question the Beca assumption in particular (further investigations into

the original McDermott Miller survey results would be needed to identify the source of the problem).

The Beca report does not provide useful comparisons of its traffic volume estimates with those from the GWRC main modelling. However it does conclude that:

- The revenue-maximising toll would be around $2 for traffic using the whole length of TGM.
- At these toll levels, some 70% of the expected untolled traffic would divert back to the existing route at the southern end (north of Linden), and 55% divert back at the northern end.
- Based on these toll levels, annual toll revenues in 2021 would be up to $7M.
- The high diversion rates and the low revenues reflect the very low predicted time savings between TGM and SH1 once TGM is constructed.

D2.4 Economic Evaluation

Most of the economic evaluation work undertaken on the TGM scheme has focused on the untolled option, with the tolled option usually being given only secondary consideration. Further, much of the evaluation work has not been comprehensively documented. The following thus provides a brief summary of the evaluation work undertaken, as we understand it, and presents key results most relevant to this project (including some of our own estimates where information was not otherwise available).

D2.4.1 Main Evaluation (GWRC)

Our understanding is that GW's main benefit evaluation was essentially derived from the GWRC traffic modelling outputs for years 2016–2026 (Section D2.3.2) multiplied by appropriate unit rates (values of time, unit VOC, accident cost rates, etc.). Outputs were derived for both the untolled situation and the revenue-maximising toll situation. Route security benefits were taken from work by Beca for GWRC (Reference 6), and taken as the same for untolled and tolled situations.

We understand average VTTS were used throughout, for both untolled and tolled benefit estimates.

Results and interpretations from the main evaluation are given below.

D2.4.2 Parallel Evaluation (Beca)

The Beca 'Parallel Traffic Modelling' report (Reference 4) was designed *"to provide an 'independent' check on the quantum of economic benefits and revenue predicted by the GW analysis"*. While the report estimated maximum toll revenues and traffic volumes in this situation, as far as we can tell its evaluation work was limited to the untolled case: *"The economic evaluation was undertaken on the untolled scenario, using the all-vehicle model (as opposed to the multi-class toll choice model)."*

Beca concludes that *"the year 2021 annual benefits for TGM (untolled) would be in the range $250-300 million NPV….."* (these benefits appear to relate to travel time, VOC and

trip reliability only). We note that these benefits appear to be more than twice those estimated by GWRC (see below): the reasons for this difference are not clear to us, but may in part relate to the base year chosen for discounting.

D2.4.3 Evaluation Results and Comments

Table D2.1 sets out the latest (mid-2004) economic evaluation results for the TGM project, as both an untolled scheme and a tolled scheme, in both cases relative to a 'do minimum' case. It also draws out the key differences between the tolled and untolled cases.

Cases A and B are two versions of the evaluation results for the untolled scheme, based on GWRC information (including advice from Tim Kelly). Taking the two versions together:

- PV costs is $362M.
- PV benefits is in the range $196M to $227M.
- The resultant BCR is in the range 0.54 to 0.63.

Cases C and D are the tolled equivalent of case B (based on advice from Tim Kelly). The (gross) costs are unchanged from Case B; the gross benefits are reduced consistent with the lower diversion to the new route; and toll revenue of PV$50M is raised. Ignoring the effects of the toll revenue (being a transfer payment) on benefits and costs gives a BCR of 0.40 (compared with 0.63 in case B). The leveraged BCR (in which toll revenue is deducted both from the benefit numerator and the cost denominator) is lower still, at 0.30: this leveraged BCR reflects the scheme merits from the viewpoint of the funding agency.

Cases E, F and G represents adjustments to cases C and D allowing for:

- a modified estimate of user benefits in the tolled situation; and
- estimated capital and recurrent costs associated with the tolling system itself (these do not appear to be included in the GWRC cost estimates).

Cases F and G may be compared to cases C and D. They involve additional PV costs of $21M; and reduced PV benefits of $11M to $37M. The unleveraged BCR is now 0.28 to 0.35 (compared with 0.40), and the leveraged BCR now 0.17 to 0.25 (compared with 0.30).

Case H presents the differences between the 'best' tolled case (G) and the corresponding untolled case (A). Key results are:

- (Gross) costs increase in the tolled case, by some PV$21M, representing the additional capital/recurrent costs associated with the tolling system.
- Gross benefits reduce in the tolled case, by PV$88M. This reflects the much reduced use of the new route when tolled.
- Hence NPV reduces by PV$109M.
- Total revenue raised from tolls is PV$50M.

- In net terms (i.e. after netting toll revenues off both cost and revenue totals), net costs are PV$29M lower than under the tolled option, and net benefits are PV$138M lower.
- While the untolled BCR is in the range 0.54 to 0.61, the tolled BCR on net costs and net benefits (i.e. the leveraged BCR) is in the range 0.17 to 0.25, i.e. very substantially lower.

Key implications of these results regarding the impacts of tolling appear to be that:

- Tolling raises PV$50M in revenue but reduces the intrinsic worth of the project (as measured by net welfare benefits, i.e. NPV) by PV$109M. This indicates that tolling of the project is economically a very inefficient way of raising revenue (e.g. relative to increasing petrol prices by an equivalent amount, in which case any net loss in welfare would be very small).
- In terms of funding priorities, the leveraged BCR figures indicate the priority ranking for use of Land Transport NZ's limited funding resources. But as the leveraged BCR for the tolled case is substantially lower than the BCR for the untolled case, this casts major doubt on the case for Land Transport NZ to allocate funding at an earlier date to a tolled scheme than it would be an untolled scheme. (On a leveraged basis, the **untolled** scheme costs PV$29M more than the tolled scheme, but provides PV$138M more benefits, giving an incremental BCR of 4.8 for **not** tolling. This further indicates the economic superiority of the untolled scheme.)

One measure of the financial efficiency of tolling road schemes is the ratio of toll revenue**:**NPV loss – the higher this ratio, the stronger the case for tolling. From the figures above the ratio for TGM is 50/109 = **0.46**. By contrast, the corresponding ratio for the ALPURT B2 scheme is estimated at 66.3/48.9 = **1.36** (refer Table D1.1).

In conclusion (accepting for the present purpose that the results given are reasonable estimates of the economic impacts of the scheme, with and without tolls), we find that the case for tolling the TGM scheme is weak:

- Tolling results in a large loss of NPV (over PV $100M).
- Tolling has a very low financial efficiency ratio (i.e. toll revenue: loss of NPV).
- Tolling would be a very inefficient way of raising additional revenue for road construction and operation.
- Tolling substantially reduces the scheme's (leveraged) BCR, and hence the case for LTNZ funding the tolled scheme earlier than the untolled scheme is very weak.

The reasons that the case for tolling the TGM scheme is weak principally relate to the existence of the closely competing existing route. Except in situations of very high congestion (due to high travel demand or traffic incidents), the existing route (with committed improvements) will be only a few minutes slower than the TGM route, as the level of congestion on the existing route will be limited by the existence of the new route alternatives. Hence motorists' choice between the two routes will be very sensitive to toll levels, and the maximum toll revenue that can be raised will be very limited (in PV terms, maximum toll revenue is estimated to cover only c.13% of costs).

Table D2.1 Summary of economic evaluation results – Transmission Gully motorway.

All costs and benefits in $m (2004), PV terms
Assumes 2016 opening, base year for discounting 2004 (?), 10% discount rate
All figures relative to base case (existing route)

Case	A Untolled (GW Updates) Ref 1, 2	B Untolled (TK) Ref 10	C Tolled (TK) Excl Rev Ref 10	D Tolled (TK) Leveraged Ref 10	E Tolled (BAH) Excl Rev & Toll Costs	F Tolled (BAH) Incl Toll Costs	G (BAH) Leveraged	H Tolled-Untolled (BAH) G-A
Toll Revenue [1]	-	-	50	50	50	50	50	+50
Costs								
Capital	362	362	362	362	362	369 [3]	369	
Operation + Maintenance	-	-	-	-	-	14 [3]	14	
Total Gross	362	362	362	362	362	383	383	+21
Total Net	-	-	-	312	-	-	333	(-29)
Benefits								
TT, VOC, Reliability	112							
Crashes	15							
Incident Delays	10							
Sub Total	137				49 [2]	49	49	
Route Security	59 to 85				59 to 85	59 to 85	59 to 85	
Total Gross	196 to 222	227	145	145	108 to 134	108 to 134	108 to 134	-88
Total Net				95			58 to 84	(-138)
NPV	-166 to -140	-135	-217	-217	-254 to -228	-275 to -249	-275 to -249	-109
BCR:								
On Gross Costs	0.54 to 0.61	0.63	0.40		0.30 to 0.37	0.28 to 0.35		-4.2
On Net Costs (leveraged)				0.30			0.17 to 0.25	(4.8)

Notes: [1] Corresponds to revenue-maximising toll levels (c.$4 per car for full length)

[2] Taken as 36% of Case A benefits: this percentage is based on Reference 2 Table 10.1 and also consistent with % reduction in TGM traffic volumes on tolling (refer Section D2.3.3)

[3] Capital cost for tolling facilities estimated as follows (indicative only):

ALPURT Cap Cost (undiscounted) $16.5M

TGM Cap Discount factor 0.426

Hence TGM discounted cost $16.5 ∗ 0.426 = $7.0M

Tolling operation/maintenance cost taken equal to that for ALPURT, i.e. $13.7M PV

D3. Tauranga Harbour Link

D3.1 References

1. Transit NZ/Tauranga CC, 2004. Harbour Link – Consultation Briefing Document. December 2004.

2. Transit NZ/Tauranga CC, 2004. Harbour Link – Funding Consultation: Summary Document. December 2004.

3. Transit NZ/Tauranga CC, 2004. Harbour Link Consultation Proposal: Frequently Asked Questions. December 2004.

4. Website www.srnetwork.co.nz.

5. NZ Herald Articles:
   (a) 15 November 2004
   (b) 20 December 2004

6. Meeting with Andrew Scott, Transit NZ, 16 December 2004.

7. Meeting with Brian Hodge, Tauranga City Council, 16 December 2004.

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

9. Advice from Beca (Andrew Murray) on impacts of removing Harbour Bridge toll on traffic volumes (email 26 January 2005)

10. Beca. 2005. Harbour Link Project – Update of Economic Evaluation. Report by Beca for Transit NZ, updated version May 2005.

11. Booz Allen Hamilton. 2005. Tauranga Harbour Link – Economic Evaluation: Peer Review. Report by Booz Allen Hamilton for Transit NZ, 10 May 2005.

D3.2 Existing Harbour Bridge

D3.2.1 **The Scheme** (Reference 1)

- Existing 2-lane harbour bridge plus approach roads
- Opened in 1988
- Funded by:
  - government grant,
  - Harbour Board grant,
  - debts, through tolling.

- Tolls were removed in July 2001, as the debt had been (almost) repaid by that time.
- At that time, tolls were $1 (each way) for cars, up to $9 for trucks.

D3.2.2 Traffic Volumes (References 1, 5(b), 7)

- After opening, volumes (AADT) were c. 8000 vpd.
- By 2001 (prior to toll removal) volumes were c. 27,000 vpd.
- Currently volumes are 38,000 – 40,000 vpd: use *"has since rocketed to levels not expected until 2015"*. Currently there is substantial congestion at some periods, and volumes are constrained by capacity limits on the bridge and approaches.

D3.2.3 User Response to Tolls

A 1999 survey of motorists using the Harbour Bridge (tolled) and the alternative SH29 route (free) estimated their trade-offs between time and the $1 toll (i.e. their values of time). A summary of this study is given in Annex A.

In summary, typical values of time (per vehicle hour) were in the range $8-$11/hour, except for trips on employer's business at around $18/hour. Effective toll elasticities were in the range -0.10 to -0.15 (relatively inelastic).

D3.2.4 Impacts of Toll Removal

Beca are currently undertaking a research project (for Transfund, now Land Transport NZ) on the impacts of the removal of the Harbour Bridge toll on traffic volumes. Preliminary advice from Beca (Reference 9) is as follows:

- Prior to the toll removal, the daily traffic flow across the bridge was 27,500 vpd.
- Following the toll removal, this increased to 37,000 vpd in 2003.
- Following the toll removal, the flows on the alternative route dropped initially from some 20,000 vpd to about 18,000 vpd; but within 6 months increased back to the pre-toll removal level of about 20,000 vpd.
- Overall, removal of the toll appears to have increased the combined cross-harbour flows by around 17% or some 8,000 vpd.

D3.3 Harbour Link Proposals

D3.3.1 The Scheme (Reference 1)

- Harbour Link is a 4-lane expressway scheme, linking central Tauranga and Mt Maunganui, involving duplication of the existing Harbour Bridge.
- Estimated scheme cost is $210M.
- Construction would start at earliest late 2005 with earliest completion in 2009.
- Current proposals, out for consultation, are to advance construction of the scheme by funding it approximately 50% from NLTF, 50% by debt funding recovered

through tolls. It is indicated that, without toll funding, the scheme is unlikely to start construction for c.10 years.

D3.3.2 **Tolling Proposals** (Reference 1)

- The tolling proposals would cover both the existing Harbour bridge and the new duplicate bridge.
- Current proposals are for tolls for cars/light vehicles in the range $1-$2 (each way), with tolls for trucks approximately twice this level.
- It is stated that the revenue-maximising toll for cars/light vehicles is estimated at about $2.
- In setting toll rates, it is noted that a balance has to be struck between:
  - the objective of maximising revenue, allowing the debt to be repaid faster and the toll removed sooner; and
  - the objective of achieving the optimum use of the network and minimising diversion of traffic from the route to non-tolled alternatives.
- It is also noted that tolls may be set/adjusted to support traffic demand management considerations (e.g. lower tolls in the off-peak periods).
- It is noted that the legislation requires the tolls to be removed once the debt and financing costs associated with the project are repaid: this period is expected to be no more than 35 years.

D3.4 Toll System Costs

The evaluation adopts the following incremental costs associated with the toll system:

- **Scheme Capital:** $18.7M (Reference 11, Table 5.1)
- **Toll System Operation and Maintenance** $3.6M pa in 2011, increasing to 4.0M pa in 2021

This Toll O&M cost is based on an estimate of $0.32 per transaction (Reference 11, Section 5.2.2). This has been estimated as a unit charge relating to funding of back-office, marketing and customer service functions associated with the proposed national Toll Systems Project.

D3.5 Value of Time Survey and Revenue Modelling

As part of the development of the business case for the Harbour Link project, Hyder Consultants Ltd with TUTI were retained by Transit NZ to:

- Undertake a stated preference (SP) survey of likely time savings v toll trade-offs for potential users of the project, and hence to derive the perceived vaue of time distribution. This work was undertaken by TUTI.
- Using the SP results, to develop a detailed toll choice traffic model and hence to forecast toll road usage and revenues. This work was undertaken by Hyder.

While we have not sighted either the TUTI or Hyder report, we understand they are on similar lines to the work undertaken by the two consultants for the ALPURT B2 project (refer Section D1).

D3.6 Traffic Modelling and Economic Evaluation

D3.6.1 Traffic Modelling Methodology (Reference 10)

Traffic modelling to provide the basis for the economic evaluation was undertaken by Beca, based on the Tauranga Transport Model (Reference 10, Section 3). In summary, model components include:

- Car driver 3-step model (trip generation, distribution and assignment).
- Three model time periods (weekday AM peak, interpeak, PM peak).
- Forecasting years 2011, 2021.

Model amendments made for the purpose of the economic evaluation of the Harbour Link toll scheme were principally:

- To model the traffic response to tolls, a single-class route-choice model was used in place of the Hyder more detailed choice model. Testing indicated that the single-choice model predicted flows on the bridge were very similar to the Hyder model.
- No significant upgrades of the alternative route were assumed.
- The model validation was adjusted in some areas to better match 2003 observed traffic flows.

A 'Fixed Trip Matrix' (FTM) approach was adopted for traffic modelling and evaluation purposes, as earlier agreed with Transit NZ and Land Transport NZ. The matrix used was that corresponding to the 'do something' situation, i.e. incorporating the effect of the toll on cross-harbour demand. A number of alternative estimates of this matrix, differing according to suppression and diversion effects, were developed for sensitivity testing purposes.

As the Beca model forecasts of use of the Bridge were greater than those conservatively estimated in the Hyder work, the Hyder toll revenue estimates were factored (up) to derive revenue estimates for the economic evaluation.

D3.6.2 Economic Evaluation Methodology (Reference 10)

The economic evaluation was undertaken consistent with PEM. Features worthy of note include:

- 25-year evaluation period, including 3.5 years construction period.
- Matrix-based assessment of user benefits (consumer surplus, using the FTM inputs).
- Use of average resource values of time (including for congested travel time and trip reliability), as specified in PEM.
- Allowance for cyclist and pedestrian benefits.

- Annualisation of benefits from the three modelled periods, based on a relationship between flow and travel time benefits derived from the traffic model.

Two BCR measures were calculated:

- Base (unleveraged) BCR = $\frac{\text{PV Gross User Benefits}}{\text{PV Gross Costs}}$
- Leveraged BCR = $\frac{\text{PV Net User Benefits}}{\text{PV Net Costs}} = \frac{\text{PV Gross User Benefits} - \text{PV Toll Revenue}}{\text{PV Gross Costs} - \text{PV Toll Revenue}}$

  where:

  Gross Costs = (Infrastructure + land) capital costs
  + Toll system capital costs
  + Toll operations/maintenance costs
  + Other operations/maintenance costs

D3.6.3 Economic Evaluation Results (Reference 10)

Table D3.1 sets out the latest (May 2005) economic evaluation results for the project, as both a tolled and untolled scheme, in both cases relative to a 'do minimum' base. We also show the key differences between the tolled and untolled schemes[1].

The main findings in relation to these differences (i.e. reflecting the effects of tolling) in PV terms are:

- Both capital costs and recurrent costs increase. Total (discounted) gross costs increase by $40.1M (24%).
- Gross benefits (i.e. excluding toll payments) reduce by two-thirds or some $340M.
- Hence NPV reduces by $380M, to a negative value.
- Total revenue raised by tolls is $115M.
- In net terms (i.e. after netting toll revenues off both costs and benefits), net costs are $74M (45%) lower than under the untolled option and net benefits $454M (89%) lower.
- The untolled BCR is 3.09.
- The tolled BCR on gross costs and benefits (i.e. the base or 'unleveraged' BCR) is 0.84, while the figure on net costs and net benefits (i.e. the 'leveraged' BCR) is 0.63: both results are very much lower than the untolled figure.

[1] It should be noted that the tolled scheme was evaluated for several toll levels and using a range of assumptions in regard to future year matrices. These different toll levels/matrices resulted in considerable variations in BCR results. For simplicity here, we show the results for one of these tests only.

Table D3.1 Summary of economic evaluation results for Harbour Link Project.

All costs and benefits in NZ$M (2004), PV terms (3.5 year construction, 21.5 year operation) *All figures relative to a 'Do Minimum' base*			
Item	**Untolled Option**	**Tolled Option[1]**	**Tolled – Untolled**
Costs:			
Capital	165.6	178.4	
Maintenance	0.3	0.3	
Toll Operation & Maintenance	**–**	27.4	
Total	**165.9**	**206.0**	**40.1** (+24.2%)
Benefits:			
Travel Time	377.8	133.5	
Congested TT (CRV)	58.8	22.2	
Trip Reliability	39.2	13.8	
Vehicle Op Costs	33.4	1.7	
Pedestrian/Cycle Costs	1.0	1.0	
CO_2 Costs	1.7	0.1	
Total	**511.8**	**172.3**	**–339.5** (-66.3%)
Revenues:			
Revenue Total	**–**	**114.5**	**114.5**
Net Costs	**165.9**	**91.5**	**–74.4** (-45%)
Net Benefits	**511.8**	**57.7**	**–454.1** (-89%)
NPV	**345.9**	**–33.7**	**–379.6**
BCR:			
Base (On Gross Costs)	**3.09**	**0.84**	**–8.5**
Leveraged (On Net Costs)		**0.63**	**(6.1)**

Source: Reference 11.

Notes [1] Relates to Beca tolled test 2 ($1.25 toll level for cars/LCV, matrix based on gravity modelling assuming $1.25 toll). This test represents the 'base' tolled test undertaken by Beca; but it should be noted that all the other tolled tests undertaken resulted in higher BCR results than test 2.

In summary, based on the results presented (Beca test 2) we conclude that the key economic effects of tolling are:

- it raises some $115M (PV terms) in revenue,
- it increases the PV net costs by some $40M,
- it reduces the intrinsic work of the project (as measured by net welfare benefits, or NPV) by some $380M,
- it reduces the BCR values (both unleveraged and leveraged) to significantly less than 1.0, casting doubt on the case for earlier funding of the project as a toll scheme.

D3.6.4 Further Comments on the Evaluation Results (Reference 11)

Booz Allen was asked by Transit NZ to undertake a peer review of the economic evaluation results of the scheme as prepared by Beca and described above. The following

summarises the main issues identified in this peer review as relevant to this research project:

(i) Use of 'Fixed Trip Matrix' (FTM) approach

Beca used a FTM approach for all tests undertaken, based on the forecast matrix in the 'do something' case. However this range of tests indicated that the benefit estimates are very sensitive to the 'do something' matrix used, indicating that they would also be sensitive to the choice of matrix in the 'do minimum' case. Thus use of a variable trip matrix (VTM) approach is likely to result in significant changes in the benefit estimates and hence the BCR results.

While we understand that use of the FTM approach for evaluation of such schemes is standard Land Transport NZ practice (as in PEM), these findings do suggest a case for exploring use of the VTM approach (perhaps in addition to the FTM approach) in the case of major schemes with high levels of congestion.

(ii) Valuation of travel time savings

As noted in the case of the ALPURT project, the use of average values of time for evaluating the toll options will produce substantial distortions in the evaluation results. It is likely to substantially over-state the time-related disbenefits (as perceived by these affected) that arise from tolling.

Our indicative estimates suggested that these disbenefits as estimated by Beca (using the PEM methodology) should be broadly halved, if they are to better reflect motorists' perceptions on the value of time changes in the tolled case. On this basis, the BCR results for the tolled option shown in Table D3.1 would increase substantially – from 0.84 to around 1.6 for the base (unleveraged) BCR, and from 0.63 to around 2.3 for the leveraged BCR. This is clearly a critical issue in relation to the economic evaluation of tolling schemes.

D3. Annex: Summary of Findings from Tauranga Revealed Preference Survey

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

This paper reports on a 1999 survey of motorists using the Tauranga Harbour Bridge (tolled) and the main free alternative route (SH29). Motorists were asked their travel time, estimated travel time by the alternative route, trip origin/destination, trip purpose and vehicle occupancy.

Some 5600 usable route choices were obtained: of these, some 2200 related to 'traders', while a further 800 were 'dominants'.

A multinomial logit (MNL) model was used to derive values of time from the data-set.

The following Table D3.2 provides a summary of the key analysis results. Based on these results, and allowing for the trip purpose and vehicle class mix at different time periods, the paper recommends (tentatively) that the following VTTS figures be adopted for forecasting purposes:

AM peak	$10/hour
PM peak	$11/hour
Interpeak	$12/hour

Table D3.2 Tauranga Route Choice Modelling Results.(1)

Trip Purpose	Value of Time		Toll Route Demand Price Elasticity(2)
	$/hour	% Mean Wage Rate(3)	
Commuting	8.35	38	−0.14
Personal Business	9.64	44	−0.15
School	4.50	20	−0.65
Social/Recreational	10.49	48	−0.13
Leisure	7.53	34	−0.10
Employer's Business	17.66	80	−0.10
All Car Travel			−0.11

Notes:

(1) Taken from Table 3 and Table 7 in the reference.

(2) Represents point elasticities (not necessarily valid over extended range of price changes).

(3) Based on mean household income of $22/hour (may not be correct).

D4. Other Tauranga Toll Roads

D4.1 References

1. NZ Herald Articles:
   (a) 15 November 2004
   (b) 20 December 2004

2. Meeting with Andrew Scott, Transit NZ, 16 December 2004.

3. Meeting with Brian Hodge, Tauranga City Council, 16 December 2004.

4. Advice from Brian Hodge, Tauranga City Council (email 12 May 2005).

D4.2 Route K

D4.2.1 **The Scheme** (Reference 1(a))

- 5 km 2-lane expressway, no intermediate intersections, 100 km/h speed limit.
- Functions as link road between Kaimai/Hamilton route and port.
- Opened 26 July 2003.
- 100% debt funded through TCC, with debt being repaid by tolls. Initial debt level $53M.
- Only toll road in NZ currently – approved by specific legislation in 2000.
- Tolls $1 for cars, up to $4 for trucks (each way).

D4.2.2 **Planning Considerations** (References 3, 4)

- Indicated that scheme design likely to be rather different if route not tolled – likely to be more intermediate intersections, resulting in higher traffic volumes.
- Also indicated that scheme has opened up a new area for development: plans are being progressed for residential development (2500 lots) and industrial development (200 ha), which will rely on Route K for access. In the absence of tolling, it is likely that such developments and associated road access would have occurred substantially later.

D4.2.3 **Traffic Volumes and Response to Tolls** (References 1(a), 3, 4)

- Traffic volumes and toll revenues to date (after 18 months operation) are stated to be substantially below the forecasts made prior to construction (modelling was carried out in 1997-1999). Usage by cars in particular is substantially less than forecast.
- There are a number of factors contributing to the lower than expected usage:
  - The traffic modelling assumed the retention of tolls on the Harbour Bridge.

The removal of the tolls has resulted in increased congestion on the Bridge and approaches, thus making use of Route K less attractive for port-bound traffic. This is mainly an issue for heavy trucks between the port and the Waikato.

- Some trucks are said not to be using the road on principle (as they claim they are already paying RUC and tolls constitute double charging).
- The use of alternative routes by significant volumes of trucks has lead to a heavy truck ban on one route (Cambridge Road) following resident protests; but this has to an extent resulted in the transfer of the problem to another route through residential areas (Moffat Road).
- The traffic modelling assumed speed restrictions (50 km/h) on the parallel Cambridge Road route, that were not found to be justified by LTSA. This has reduced the potential travel time savings with the toll route.
- Despite increased traffic control measures (small roundabouts, traffic lights at intersections, light-controlled pedestrian crossings) on the parallel Cameron Road route, traffic has not diverted to the toll route to the extent expected.

- The toll route traffic volumes have increased by over 50% since opening of the road and are still growing, but are still only around half the original model estimates. This shortfall primarily relates to car traffic (truck volumes are at about the levels predicted, although total truck traffic in the area exceeds the predicted levels).
- Recent traffic modelling based on the currently prevailing conditions more-or-less replicates the existing traffic volumes on the route.

D4.3 Other Regional Arterial Routes

D4.3.1 The Schemes (References 2, 3)

- Two major schemes proposed as part of the Tauranga Strategic Road Network are the Eastern Arterial (Te Puke Bypass) and the Northern Arterial.
- These are at a relatively early stage of development, but planning to date is based on them being toll roads.
- However, no decisions have yet been taken on funding. Candidate funding sources include:
  - NLTF,
  - tolls,
  - regional petrol tax,
  - local rates,
  - developer contributions.

D4.3.2 Planning Considerations

- If routes are not tolled, then it is likely that construction would occur significantly later.
- If not tolled, also likely that designs would be varied, in particular would be likely to include more connections with the rest of the network.

Appendix E:

Tolling Case Studies – Australia

E1: Melbourne City Link

E2: Melbourne Mitcham – Frankston Freeway

E3: Sydney F3 – M2 Link

E4: Sydney Lane Cove Tunnel

E5: Sydney Warringah Peninsula Transport Options

E1. Melbourne City Link

E1.1 References

1. Allen Consulting Group. 1996. The Economic Impacts of Melbourne City Link: Transurban Project. Report by the Allen Consulting Group to The Melbourne City Link Authority, April 1996.

2. Allen Consulting Group. 2002. Estimating the Economic Benefits of City Link. Report by the Allen Consulting Group to Transurban City Link, 2002.

3. Allen Consulting Group. 2003. Benefits of Public Investment in the Nation's Road Infrastructure (Update Report). Report by the Allen Consulting Group to the Australian Automobile Association, May 2003.

4. Odgers, J., Wilson, D. 1999. A Systemic Analysis of the City Link Project, Melbourne, Australia. Paper to 23rd ATRF, Perth.

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9. City of Stonnington. 2003. City Link Impact. A submission, August 2003.

E1.2. The Project

- The Melbourne City Link scheme was a major freeway project designed to link up the main radial routes into the central/inner areas of Melbourne.
- It comprises new road links to 6-lane freeway standard (including a new bridge over the River Yarra and a tunnel under the Domain) together with upgrading and widening of existing radial freeways.
- The scheme has been undertaken as a BOOT (Build, Own, Operate, Transfer) project, by the Transurban group.
- Estimated capital costs were c.$1500M (A$ 1993).
- The scheme was constructed over the period 1995/96 – 1999/00.

E1.3 Traffic Forecasts and Impacts

E1.3.1 Traffic Forecasting (Reference 4)

Full details of the traffic modelling/forecasting methods have not been obtained.

However, in respect to the market research used to establish diversion rates, we note the following comments:

> *One significant failure of Transurban's corporate governance policies centres on the method used to compute the "diversion factors". This critical parameter was based on questionable research processes.*
>
> *Preparation of this model in a form suitable for application on the Melbourne road network necessitated specialist research in the form of a stated preference survey which* ***involved a sample of approximately 280 households and 180 freight operators****. The survey results enabled estimates to be made of the impact of the implementation of a toll for use of the Link segments* ***and hence provided the ability to forecast tolled traffic volumes and projected revenues****. (The Melbourne City Link Prospectus, 1996:42)*
>
> *Without delving deeply in statistical waters, one must surely question the validity and reliability of any survey of such a crucial kind being based (i) on one sample only, (ii) on such a small sample size, given the quite 'revolutionary' road usage scheme being investigated, and (iii) using only one research method.*

E1.3.2 Tolled v Untolled Traffic Volumes

- Toll diversion of 21% of untolled volumes (Reference 6).

E1.3.3 Actual v Forecast Traffic Volumes (Reference 5)

Analysis of traffic volumes on the route in 2001 showed that:

- Volumes on the N/W and S links were between 15% and 39% below forecasts.
- Volumes on the SE links were between 4% and 9% above forecasts.

It is suggested (in the absence of sufficient research) that main reasons for these discrepancies are:

- More alternative major roads are available in the N/W sector – hence it is easier for motorists to avoid City Link.
- Motorists from the SE are generally more affluent and/or will have their motoring costs paid by employers, relative to those in the N/W.

E1.4 Economic Impacts

E1.4.1 Actual Economic Forecasts and Outcomes

(A) **Ex-ante evaluation** (Reference 1):

Refer Table E1.1 below.

(B) **Ex-post evaluation** (Reference 3):

- Direct benefits $4.0 billion PV (time savings, VOC savings, accident benefits, fleet-mix benefits, off-road benefits).
- Direct Costs $2.0 billion PV.
- BCR 2.0.

Table E1.1 Cost Benefit evaluation summary.

Item	Amount
Key Evaluation Parameters	
Base Year for Discounting	1993
Prices	A$1993
Discount rate	8% pa
First full year of operation	2000/01
Evaluation period	31.5 years of operation
Capital Costs	**$1515M**
Benefit (year 2000/01):	**$Mpa**
Travel time savings	118
VOC savings	3
Accident cost savings	13
Fleet mix savings	51
Off-road benefits	51
Total annual benefits	**228**
Evaluation Summary	
PV Costs	$1236M
PV Benefits	$2521M
NPV	$1285M
BCR	2.04

E1.4.2 Untolled v Tolled Economic Outcomes (Reference 6):

Tolling resulted in:

- Net benefit (NPV) reduction from $2.7 billion to $1.3 billion,
- Community BCR reduced from 3.8 to 2.0.

E1.5 Planning and Risk Issues (References 4, 5)

The Melbourne City Link Act (MCLA) and the Concession Deed between the State Government and Transurban place many obligations on the Government, including requirements to compensate Transurban for a wide range of 'material adverse effects'.

The Vic Government agreed:

- to fund certain state works during the construction phase,
- to implement 'Agreed Traffic Measures',
- to amend various pieces of legislation to protect Transurban's financial and legal position.

'Material adverse effects' which require the State Government to compensate Transurban include events such as:

- alterations to traffic conditions,
- new roads or public transport that are perceived to adversely affect the project,
- changes in any state or federal laws that might be adverse,
- industrial action,
- *force majeure* events.

The concession period granted to Transurban is 33.5 years. However it may be reduced to as short as 25.5 years, if all debt has been repaid and the after-tax equity return exceeds 17.5%. Conversely, it may be increased up to 53.5 years. Such increases are one means which may be used to compensate Transurban for material adverse effects. A variety of other means of compensation are also allowed under the MCLA, e.g.:

- vary the tolling schedule,
- financial contributions from the Vic Government.

As noted by the Vic Auditor General, the overall effect of the various provisions is that a large share of the risks inherent in the project are not borne by Transurban, but by users of City Link and by the state.

E2. Melbourne Mitcham – Frankston Freeway

E2.1 References

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E2.2 Traffic and Economic Impacts – Tolled v Untolled

(Reference 1)

E2.2.1 Traffic Diversion

- Tolls estimated to cause 55% diversion rate of 'free' users from Scoresby Freeway:
  - high factor reflects relatively good speeds on alternative free routes.

- *The decision to directly toll the Scoresby Freeway is economically stupid because the expense of building a high-quality road is wasted when only half of the potential users actually end up using it. The other half of the freeway's potential users will continue to opt for the stop-start arterial roads, where accidents are three times as high, petrol consumption and motor vehicle pollution is 50% higher, and business travel time costs are doubled.*

E2.2.2 Economic Evaluation

- BCR for Scoresby Freeway estimated at 5.2 for 'free' route, only 1.0 for tolled route.

E3. Sydney F3 – M2 Link

E3.1 References

1. SKM. 2004. Sydney F3 to Sydney Orbital Link Study. Summary Report and Technical Report to DOTARS, NSW RTA and DIPNR.

2. SKM. 2004. F3 to Sydney Orbital Link Study: Working Paper No.7. Economics and Finance Report. Report to DOTARS, NSW RTA and DIPNR, March 2004.

3. SKM. 2004. F3 to Sydney Orbital Link Study: Working Paper No. 4. Traffic and Transportation. Report to DOTARS, NSW RTA and DIPNR, March 2004.

E3.2 The Project

- Proposed new National Highway link through northern Sydney between the F3 Sydney – Newcastle Freeway and the Sydney Orbital route (M7). It would effectively replace the existing interim National Highway, which runs along Pennant Hills Road.
- Range of options being considered. Favoured option is about 8 km length, largely in tunnel and broadly along the Pennant Hills Road alignment. Dual 2-lane and dual 3-lane schemes are being assessed.
- Capital costs are approximately A$1.7 billion for the dual 2-lane scheme and A$2.0 billion for the dual 3-lane scheme.

E3.3 Traffic Appraisal of Preferred Route Options

Modelling was undertaken to assess how traffic volumes and toll revenue would vary with the level of the toll charge. It was found that:

- In 2021 peak periods, maximum revenue was derived from $3.50 toll per user (including trucks).
- The toll elasticity varies substantially with the toll rate, starting from around –0.1 at low tolls but increasing to over –1.0 as tolls exceed the $3.50 level. (This result would confirm that the use of constant toll elasticities is inappropriate for forecasting toll diversion effects.)

As a result of these analyses, a $3.50 toll for all vehicles was assumed in the subsequent testing. (Note: No off-peak modelling appears to have been undertaken.)

The first part of Table E3.1 shows the impacts on traffic volumes using the route of imposing the optimum toll level. It shows that this toll reduces peak traffic volumes on the link by 45% to 50%, and AADT volumes by 44% (year 2011).

It is noted that reasons for this relatively high diversion are:

- The relatively modest time savings from using the new link – in 2011 peak periods about 15 minutes on the tolled route (10 mins if untolled), but less at non-peak times.
- Likely resistance to increasing tolls in the corridor, given that a large proportion of potential users would face other toll links.

E3.4 Economic Evaluation of Preferred Route Options

Table E3.1 presents a summary of the economic evaluation results for options using the preferred route, with or without tolls, and including both dual 3-lane and dual 2-lane options. Note that, under tolling options, neither the capital costs nor the benefits have been adjusted for the toll payments (i.e. cost figures are not 'leveraged').

The effects of introducing tolling (assuming no change in road standard) are to:

- Increase PV capital costs by $74M.
- Decrease PV benefits by $242-262M (18-19%).
- Decrease NPV by $316-336M, hence reducing BCR by around 0.25-0.30 (in both cases from rather greater than 1.0 to rather below 1.0).

Table E3.1 Summary of road user cost benefit analysis results (preferred route).
All figures are PV incremental to base case, at 7% real discount rate, 2003 prices.

Item	No Toll		Toll (A$3.50)		Toll v No Toll		
	Dual 3-lane	Dual 2-lane	Dual 3-lane	Dual 2-lane	Dual 3-lane	Dual 2- lane	Dual 2-lane Toll v Dual 3-lane No toll[2]
Traffic Volumes (2 way, 2011)							
AADT	69,500		38,900		–30,600 (–44%)		
Peak Hour	6300	5800	3200	3200	–3100 (–49%)	–2600 (–45%)	
Economic Analysis							
PV Capital Costs (A$M)	1282	1085	1356	1159	+74	+74	–123
PV Benefits [1] (A$M)	1352	1344	1090	1102	–262	–242	–250
NPV (A$M)	70	259	–266	–57	–336	–316	–127
BCR	1.05	1.24	0.80	0.95	(–3.5)	(–3.3)	(2.0)

[1] Benefits are net of incremental operating/maintenance costs and external costs.

[2] This column is included as the report states (p. 16-4) that: The conclusion from this analysis is that the link should be constructed as two lanes with a toll or three lanes without a toll.

The reports available do not provide the PV of toll revenues. However an indicative calculation is as follows:

- Total AADT on tolled route (dual 3-lane) in 2021 = 45,800 (Reference 3, Table 17-4).
- Hence annual toll revenue = 45,000 ∗ 365 ∗ $3.50 = $58.5M.
- At 7% discount rate, PV factor is approx 100/7 = 14.
- Hence PV toll revenue = 58.5 ∗ 14 = $820M.
- Deducting the GST component of this gives a PV toll revenue of about **$750M.**

Using these figures, key findings in relation to the performance of the tolling scheme for the project (based on the dual 3-lane option) are:

- Gross toll revenues are around PV $750M.
- Costs associated with the toll infrastructure and operation are PV $74M, i.e. some 10% of the toll revenue.
- Net toll revenues (PV $676M) cover 53% of the costs of the untolled scheme (PV $1282M).
- The net toll revenue (PV $676M) may be compared with the NPV loss of $336M, a ratio of 2.01.
- The 'unleveraged' BCR reduces from the base figure of 1.05 to the tolled figure of 0.80.
- The 'leveraged' BCR for the tolled scheme is estimated at (1090–750)/(1356–750) = 0.56, i.e. significantly lower than the untolled estimated.

E4. Sydney Warringah Peninsula Transport Options

E4.1 References

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2. Bureau of Transport and Regional Economics, DoTaRS. 2003. Improving Transport on the Warringah Peninsula: Issues and Options. *BTRE Working Paper 53*, 2003.

E4.2 The Project

The study examined a number of schemes to improve transport facilities between the Warringah Peninsula and Sydney's Lower North Shore, involving substantial dual 2-lane tunnel schemes (5-8 km length). Options were evaluated both with and without tolls.

E4.3 Economic Evaluation

Table E4.1 summarises the economic evaluation results for the two tolled options.

Table E4.2 summarises data available on comparisons between tolled and untolled options. (These two tables are taken from two different sources, and there must be doubt as to whether they are consistent.)

Table E4.2 results indicate that:

- Tolling reduces the total resource costs of travel, by around $14M pa/$18M pa in the two options.
- The main component of this saving relates to reductions in travel time resulting from tolling. (This is a somewhat unusual, but plausible, result: more usually, imposing tolls increase overall network travel time.)
- The tolls raise around $35M pa.
- Total user costs (including toll payments) increase by around $21M/$18M pa in the two options: the additional money costs associated with the tolls exceed the total value of the time savings.

Table E4.1 Economic evaluation summary – tolled options (based on 25 year evaluation period, 4% discount rate).

Item	Scheme A	Scheme B
Costs		
Construction – Capital ($M)	956	651
Operating Costs ($M pa)	15.7	13.0
Benefits		
Travel Time Savings ($M pa) (year 1)	255	232
Economic Evaluation Outcome		
NPV (2002 $M)	3800	3500
BCR	5.0	6.4
Financial Outcome		
Toll Charge ($/vehicle trip)	3.50	3.50
Vehicle trips/day (year 1)	52,000	50,000
Toll revenue ($M, year 1)	66	64
Financial NPV ($M)	–282	–4

Source: Reference 2, Table 5.2

Table E4.2: Evaluation comparison of tolled v untolled options (based on year 2020 estimates).

Item	Scheme A (Tolled v Untolled)	Scheme B (Tolled v Untolled)
Time Costs		
1. Travel time increases	–$18.0M	–$22.0M
Money Costs		
2. Toll revenues	+$34.8M	+$35.9M
3. Other user money costs	+$4.4M	+$3.6M
4. Total user money costs	+$39.2M	+$39.5M
Total Resource Costs		
Items 1 + 3	–$13.6M	–$18.4M
Total User Costs		
Items 1 + 4	+$21.2M	$17.5M

Source: Reference 1, Table 3.

Appendix F:

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[2] Appendix A: Literature Summary & Review: Traffic Modelling Methods

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Appendix D: Tolling Case Studies – New Zealand

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D2: Transmission Gully Motorway

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D3: Tauranga Harbour Link

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E4: Sydney Warringah Peninsula Transport Options

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Implications of Selected Urban Road Tolling Policies for New Zealand

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