Benefits of the inclusion of active transport in infrastructure projects

Transport and Main Roads

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SKM

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Contents

Document History and Status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
1	27/6/2011	C. Munro	J. Frew	27/6/2011	

Distribution of Copies

Revision	Quantity	Issued to
1	PDF	TMR

Printed:	16 May 2011
Last saved:	28 June 2011 08:51 AM
File name:	D:\Documents and Settings\CMunro\My Documents\TMR AT Benefits\Deliverables\SB19226 Benefits of Active Transport v1.0.docx
Authors:	Cameron Munro
Project manager:	Cameron Munro
Name of organisation:	Department of Transport and Main Roads
Name of project:	Benefits of inclusion of active transport in infrastructure projects
Document version:	Draft
Project number:	SB19226

Executive Summary

The economic appraisal of active transport modes, including walking and cycling involves the identification and monetisation of the incremental net benefits that are directly attributable to the investment in active transport infrastructure. Conventional transport appraisal typically underestimates the contribution of non-motorised transport, in part because some benefits such as improvements in health are either omitted or not adequately quantified. Appraisal frameworks that fail to adequately capture effects of active transport may understate the total economic value of transport infrastructure and result in an inefficient allocation of investment to active transport projects and programs.

The quantifiable incremental benefits of active transport can emanate from associated reductions in the cost of:

- road congestion,
- pollution and greenhouse gas emission,
- travel time savings,
- vehicle operating costs, road infrastructure provision, and
- the provision of health care.

The largest expected benefit from active transport relates to improvements in health from increased physical activity, reduced morbidity and mortality. The magnitude and type of active transport benefits that are attributable to a specific infrastructure asset will vary according to the type of initiative and location. For example, cycling generally increases exposure to the risk of injury, compared to motorised transport. However, this increase in risk exposure needs to be offset against the safety benefits that increased participation in cycling and dedicated active transport infrastructure provide. Methodological and projects specific issues such as these should be translated into the appraisal framework and reflected in the economic unit costs..

While the appraisal of active transport is an emerging field, it is necessary to maintain consistency with accepted transport appraisal methodologies. The following summary of project benefits and unit values draws upon best practice road and public transport appraisals, adapted, where possible, to reflect the nuances of active transport in Queensland. A range of sensitivity tests are recommended throughout the document where there is debate in the literature or uncertainty surrounding data inputs for specific benefit categories. All appraisal results should be understood within the context of the plausible range of results offered by the upper and lower bounds of this sensitivity range.

■ Table EX.1: Benefits summary

Benefit	Value (2010$/km)	Sensitivity testing	
		Lower bound	Upper bound
Health			
- Walking	$1.68	$1.23	$2.50
- Cycling	$1.12	$0.82	$1.67
Decongestion	$0.207	$0.060 (off-peak)	$0.340 (peak)
Vehicle operating costs	$0.350		
Injury costs			
- Walking	-$0.24		
- Cycling	-$0.37		
Noise reduction	$0.0091	$0.0065	$0.0117
Air quality	$0.0281	$0.0275	$0.0288
Greenhouse gas emissions	$0.0221	$0.0196	$0.0248
Infrastructure (roadway) provision	$0.052		
Parking cost savings	$0.016		

Note: Negative values imply a disutility or increased costs.

The capital costs of active transport projects will vary widely depending on the extent of infrastructure works required, and whether any land resumption is required. As such, ‘standard’ capital costs are unlikely to provide a good indication of capital costs in most situations. The operating costs of active transport projects will be affected primarily by the path material (asphalt or concrete), quality of the sub-grade, presence of lighting and requirements for sweeping or vegetation maintenance. However, the average cost per bicycle or pedestrian km is likely to be much lower than for motorised transport. While the average costs for all modes vary widely, our estimates suggest that the average operating costs of active transport are several orders of magnitude smaller than motorised transport (Table EX.2).

■ Table EX.2: Standard operating cost comparison

Mode	Operating cost per passenger-km
Bicycle	
- concrete path	\$0.0005[1]
- asphalt path	\$0.0052[2]
Bus	\$0.221 - \$0.76[3]
Train	\$0.093 - \$0.41[3]
Car	\$0.0194[4]

[1] 3 m concrete path with 1,000 cyclists per day on a soft sub-grade.

[2] 3 m asphalt path with 1,000 cyclists per day on a soft sub-grade.

[3] Lower bound is ATC (2006) standard cost converted to passenger-km while upper bound is from TransPerth (2011).

[4] RTA (2003) for average maintenance costs and assuming average vehicle occupancy of 1.3.

The benefit unit values were applied to several existing and proposed active transport projects, suggesting a benefit-cost ratio for these projects from 0.3 to 2.4. Every project is different, and so general guides to the likely benefits of active transport projects are likely to be misleading. However, as a starting point for an active transport appraisal the model suggests that:

- For an inner urban active transport project that is off-road:
  - 1,000 cyclists per day generate discounted benefits of around \$15m over a 30 year appraisal period,
  - 1,000 pedestrians per day generate discounted benefits of around \$7m over a 30 year appraisal period,
- For an outer urban or rural active transport project that is off-road:
  - 1,000 cyclists per day generate discounted benefits of around \$20m over a 30 year appraisal period,
  - 1,000 pedestrians per day generate discounted benefits of around \$12m over a 30 year appraisal period.

The differences between inner urban and other areas are attributable to the varying diversion rates between the locations. In inner urban areas a larger proportion of demand is likely to be existing active transport users diverting from other routes, which offer lower net benefits than outer urban and rural locations where a larger proportion of demand is all-new (induced) travel or more likely to have diverted from private car.

In all the test cases the vast majority (around 90%) of the benefits are due to health improvements for cyclists and pedestrians. However, there are significant knowledge gaps in understanding which groups in the population uses active transport projects, and exactly what health improvement is gained from providing such infrastructure. These uncertainties imply that the approach should be treated with caution until further research is undertaken to refine the health benefits in particular.

1 Introduction

Sinclair Knight Merz (SKM) and Pricewaterhouse Coopers (PwC) were commissioned by the Queensland Department of Transport and Main Roads (TMR) to develop a methodology to evaluate the benefits of incorporating active transport projects in wider infrastructure projects.

1.1 Purpose and scope

The purpose of this study was to:

- identify the economic benefits of active transport, and determine Queensland-specific monetary values for these benefits,
- apply the benefits in an economic appraisal framework to estimate the economic viability of existing and proposed active transport projects in Queensland, and
- identify any limitations to the approach which warrant further investigation and research.

The intent is to provide a method to TMR which can be useful in appraising active transport projects in conjunction with larger infrastructure projects, particularly road and rail projects. This economic appraisal framework provides a complementary approach to determine value for money infrastructure solutions which contribute to effective government decision making as required under the Project Assurance Framework (PAF).

The economic appraisal of active transport infrastructure investment is in its infancy. Extensive and accurate data on usage of active transport is sparse. This scarcity, combined with the timeframes of this project, mean there are a number of gaps and uncertainties identified in this report which warrant further attention. The scope of this project was therefore to synthesise the available data and provide TMR with a foundation for further research where required.

1.2 Approach

Our approach to identifying the benefits of active transport is based on three principles:

- consistent wherever possible with wider transport appraisal practice,
- supported by economic theory, and
- can be quantified with sufficient levels of confidence.

Sufficient levels of confidence are defined arbitrarily, as the limited existing research and evidence on active transport demand and appraisal means there are significant uncertainties which are deserving of further study. However, where this confidence is limited (as, for example, with the health benefit) the purpose of this study is to assist TMR in understanding the significance of these uncertainties and point to directions in which they may be improved.

1.3 Report structure

The structure of this report is as follows:

- **Section 2** discusses active transport appraisal within the wider Project Assurance Framework which governs investment decisions in the Queensland public sector,
- **Section 3** identifies the benefit streams for active transport, and provides recommended unit values,
- **Section 5** identifies indicative operating costs for off-road active transport projects,
- **Section 6** describes the application of the model to 9 example projects in Brisbane; the very high level cost and demand estimates mean that these examples serve only to illustrate the application of the model, rather than to serve as rigorous economic appraisals of these projects,
- in **Section 7** we discuss other issues which are relevant for consideration in an economic appraisal of active transport project,
- **Section 8** offers a view on further work which may be undertaken to improve our confidence in the unit values presented in this report.

2 Project assurance framework

The Project Assurance Framework (PAF) is a common approach to assessing projects across the Queensland public sector. Its aim is to maximise the benefits returned to government from project investments. PAF defines a project lifecycle as having one pre-project phase and six project stages (Figure 2.1).

- Figure 2.1: Project assurance framework

The Strategic Assessment of Service Requirement (SASR) stage is where the service need is identified. This should incorporate an assessment of active transport needs and consider such needs within the wider policy context, such as meeting the *Connecting SEQ 2031's* objective to double active transport mode share. This target would dictate that active transport need be considered as part of most, if not all, transport projects at the SASR stage. However, their appraisal would not occur until the Preliminary Evaluation (PE) stage.

The SASR requires the project proponent to define the need and outcome sought (aligned with policy objectives), and identify potential solutions. It is at this latter stage that a range of "reasonable alternatives" need be defined. This should include identification of the *status quo* option (a "do minimum" scenario), the study area and high level options (which most likely would have options which include one or more active transport components). These solutions may include infrastructure and non-infrastructure options, and combinations of both.

The SASR and subsequent stages should ensure active transport projects are given due consideration by project proponents. The policy objectives set out in SEQ 2031 to double active transport mode shares provide a strong policy incentive to consider an active transport project as part of the SASR. Furthermore, if the economic benefits of the active transport exceed their costs then it is in the interest of the project proponent to incorporate the active transport component into the wider project as this will improve the investment decision throughout each phase of the framework.

The SASR process, and the subsequent preliminary evaluation and business case (using the appraisal guidance presented in this report) should ensure that active transport projects are given due consideration as part of larger transport projects. There is every in-principle reason to expect that transport projects developed using PAF will consider active transport components. However, as the project proceeds through PAF it may be ruled out if it does not meet the service need or is economically unviable.

3 Benefits

The benefits of active transport infrastructure will accrue to users (cyclists and pedestrians) and non-users, who will benefit indirectly from, for example, reduced emissions, noise and congestion. Direct benefits accruing to users may take the form of, for example, travel time savings, direct out-of-pocket savings on vehicle costs and health benefits.

The source of economic benefits and unit values in this section are derived or sourced from either standard values in Queensland, national transport appraisal guidelines[1] or accepted methodologies using Queensland-specific values. In this section we describe the approach taken to quantify the benefits we consider meet the criteria outlined in Section 1.2.

3.1 Value of statistical life

The value of a statistical life (VoSL) is central to the valuation of road safety and health benefits which follow in this section. There are two principle ways in which VoSL can be calculated:

- *human capital:* measure value of life as the market productivity of individuals (i.e. their present value of future expected earnings) and associated resource costs, and
- *willingness-to-pay:* ask respondents how much they would be willing to pay to reduce their risk of fatal or serious injury.

Both methods will produce different VoSL estimates, with the willingness-to-pay approach producing higher values than the human capital approach. We propose the willingness-to-pay-derived estimate as recommended by OBPR (2008) be used as the base case, with a sensitivity test for the willingness-to-pay estimate derived for use in NSW (RTA, 2009) as an upper bound and the BITRE (2010) human capital estimate be used as a lower bound. This provides a range from $2,740,000 to $5,950,400 (Table 3.1).

[1] Namely the National Guidelines to Transport System Management (NGTSM (ATC, 2006)) and Austroads Guide to Project Evaluation (Austroads, 2008).

■ Table 3.1: Values of a statistical life (2010 prices[2])

	Value	Sensitivity range	
Value of statistical life	$3,876,000[1]	$2,740,000[2]	$5,950,400[3]

[1] Willingness-to-pay estimate from OBPR (2008)

[2] Human capital estimate from BITRE (2010).

[3] Willingness-to-pay estimate from RTA (2009)

3.2 Health

There is a strong body of research demonstrating the link between physical inactivity and an increased risk of weight gain and hence, type 2 diabetes, certain cancers and cardiovascular disease as well as mental health conditions such as depression (see for example Garrard, 2009). In Queensland the second most significant single contributor to the disease burden is estimated to be physical inactivity (Queensland Health, 2010).

The National Physical Activity Guidelines (Department of Health and Ageing, 1999) recommend that adults obtain at least 30 minutes of moderate physical activity on most days of the week. The most recently available data in Queensland suggest that around 54% of adults meet this guideline (Queensland Health, 2010).

There are two primary ways in which active transport can improve health outcomes:

- reduced mortality (death), and
- reduced morbidity (illness, disease and general poor health).

These conditions impose clear direct and indirect costs on the individual, as well as on those around them and society as a whole. The financial burden imposed on the health system in treating ailments associated with physical inactivity are significant; 2006-07 Australian estimates indicate that the direct cost of inactivity was around $1.5 billion (Econtech, 2007). Assuming an even distribution nationally, and that Queensland represents 20% of Australia's population, the direct cost to Queensland in 2006-07 would have been around $300 million.

To demonstrate a causal link between active transport infrastructure and improved health outcomes it is necessary to demonstrate that (a) there is a causal link between participation in active transport and improved health outcomes, and (b) that those who stand to benefit (i.e. inactive and insufficiently active individuals) would use active transport infrastructure should it be provided[3]. While evidence on the former is substantial, and described briefly in

[2] Throughout this paper prices are presented as 2010 Australian dollars unless otherwise stated. Price levels are adjusted to 2010 using the Brisbane consumer price index series from ABS Cat No. 6401.0. Quarterly indices are averaged across calendar years to provide an annual index. International prices are converted to Australian dollars in then-year prices using OECD annual PPP and exchange rate indices and subsequently inflated to 2010 prices using the Brisbane CPI index.

[3] Furthermore, as the dose-response curve is unlikely to be linear that the individual participates in active transport with sufficient duration and frequency to produce health benefits. In other words, the marginal benefit per additional active transport km will depend on exactly how active the individual is prior to this additional km.

the following section, there is far less evidence on the latter. This is clearly an area for which further literature reviews and primary research would be warranted (Section 8).

3.2.1 Evidence on causal links between active transport and health

There have been two recent systematic reviews of the literature on active transport and health:

- Oja et al. (2011) reviewed 16 cycling studies and identified strong inverse relationships between commuter cycling and mortality and morbidity among middle aged and elderly individuals, and
- WHO (2010) identified 15 studies which identified a link between walking and reduced all-cause mortality; the meta-analysis identified a relative risk of 0.78 for a walking exposure of 29 minutes per day on each day of the week, implying a reduction in mortality risk of 22% for those who participate in regular walking.

These studies identified strong causal links between participation in active transport and reduced mortality, and in some cases, morbidity among adults. The evidence for children is more limited. For this reason in the calculations that follow it is assumed the benefits from physical activity are incurred only by those aged 15 and above.

The approach taken here to quantify the benefits is to firstly estimate the cost to society of physical inactivity per inactive individual, and then to estimate the per kilometre benefit should sedentary or insufficiently active individuals commence cycling or walking as a result of the project.

3.2.2 Cost per physically inactive individual

In this section we consider the direct and indirect costs of physical inactivity separately, where:

- the **direct** health costs are those costs in hospital patient care, out of hospital medical care, medications and care services associated with treating a physically inactive individual who has developed a health condition attributable to this inactivity,
- **indirect** costs are the productivity losses incurred as a result of illness or premature death and the intangible costs of pain and suffering.

3.2.2.1 Direct costs

The direct costs to the health sector are based on the national estimates of Econtech (2007), which estimated total health care costs attributable to physical inactivity to be $1.494 bn (2006/07 prices, or $1.682bn in 2010 prices assuming growth in line with CPI). Using inactivity prevalence for Australia from 2000[4] (AIHW, 2003) of 54.2 per cent the health sector cost per inactive Australian aged 15 or older is $171 per annum (Table 3.2).

[4] The National Physical Activity Survey which is the source of this data was discontinued after 2000, meaning there is no authoritative national physical activity participation data available since 2000.

■ Table 3.2: Direct health costs of physical inactivity

Step	Description	Value	Comment
A	Direct cost of physical inactivity in Australia	$1.682 bn	Econtech (2007) adjusted to 2010 prices using CPI. Econtech use physical inactivity prevalence data for 18-75 year olds (NPAS), and health sector costs attributable to all ages. Assume herein that physical inactivity costs apply only to those aged over 14.
B	Australian population aged over 14	18,111,785	ABS Cat No 3101.0 (2010)
C	Insufficiently active population proportion	54.2%	AIHW NPAS survey 1999 (Armstrong et al., 2000)
D	Insufficiently active population aged over 14 18,111,785 x 54.2%	9,816,587	
E	Cost in physical inactivity per insufficiently active individual per annum $1.682 bn / 9,816,587	$171.32	2010 prices, inactive Australians aged 15 or older

3.2.2.2 Indirect benefits

The indirect health benefits are those benefits which come from increased productivity due to improved health and longevity as well as the intangible benefits that come from avoided pain and suffering. The indirect costs of physical inactivity in Queensland have been estimated by Jardine et al. (2010) to just over 35,000 Daily Adjusted Life Years (DALY)[5] in 2007 across three disease categories (cardiovascular disease, cancer and Type 2 diabetes – see Table 3.3). This approach neglects the joint effects of multiple risk factors on the disease categories, which will result in a significant over-estimate of the disease burden attributable to physical inactivity. However, there is not currently sufficient data to understand how much of an over-estimate this represents.

[5] DALY is a measure of overall disease burden and is expressed as the number of years lost due to illness, disability or premature death. It is the sum of Years of Life Lost (YLL) and Years Lived with Disability (YLD).

■ Table 3.3: DALY by broad cause group in Queensland attributable to physical inactivity in 2007

Broad cause group	DALY (2007)
Cardiovascular disease	21,353
Cancer	5,768
Diabetes	7,995
Total	*35,116*

Source: Jardine et al. (2010)

The monetarised cost of these DALYs is estimated by applying the value of statistical life to the number of years of life lost by the person of average age (37.2 years) living to the average life expectancy for that age (82.6 years). These calculations, shown in Table 3.4, result in an estimated cost per DALY of $85,302 (2010 prices).

■ Table 3.4: Indirect health costs of physical inactivity

Step	Description	Value	Comment
A	Value of statistical life	$3,875,952	OBPR (2008) adjusted to 2010 prices using Brisbane CPI (ABS Cat No. 6401.0)
B	Average age of all Queensland residents	37.2	ABS Cat No 3101.0
C	Life expectancy of Queensland resident of average age	82.6	ABS Cat No. 3302.0
D	Calculate undiscounted cost of year of life $3,875,952 / (82.6 – 37.2)	$85,302	82.6 – 37.2 is the average years lost. Discounting is applied to the health benefit stream in the subsequent appraisal.
E	DALYs due to physical inactivity	35,116	Jardine et al. (2010) and Table 3.3
F	Queensland resident population aged over 14	3,347,438	ABS Cat No. 3101.0 (2007)
G	Insufficiently active population proportion	46.1%	Queensland Health (2010)
H	Insufficiently active Queensland population aged over 14 3,347,438 x 46.1%	1,543,169	
I	Indirect cost in physical inactivity per insufficiently active individual per annum $85,302 x 35,116 / 1,543,169	$1,941	2010 prices

3.2.3 Per kilometre benefits of active transport

Having established the costs of inactivity per inactive individual (Section 3.2.2), it is then necessary to convert this to a unit that can be related to the predicted demand for the active transport project. There are two ways in which this has been done in the literature:

- estimate the benefit per 'new' cyclist or pedestrian (for example SQW 2007), or
- estimate the benefit per cyclist or pedestrian kilometre travelled (for example PwC 2010; AECOM 2010).

Our view is that the latter approach is preferred, as (a) there is currently very limited confidence in demand forecasting for active transport (including reliable estimates of 'new' user travel), and (b) the other benefit streams are calculated on a per kilometre basis, as is convention within transport appraisal practice.

The magnitude of the marginal health benefit per kilometre will be dependent on a number of factors, including:

- the pre-existing activity level of the individual that is undertaking the cycling or walking trip (i.e. whether they are sedentary, insufficiently active or sufficiently active),
- the length of time over which the activity takes place,
- whether the activity is undertaken at a sufficiently strenuous level to generate a health benefit,
- whether there is any substitution from other physical activities, and
- the frequency at which the activity takes place.

These issues present very significant challenges as there is scarce empirical evidence on how different segments of the population use active transport infrastructure (e.g. Fraser and Lock, 2010). Most attempts to quantify the health benefits of active transport to date assume that users of an active project would come in equal proportion from each activity prevalence group (sedentary, insufficient and sufficiently active). This is unlikely to be true in practice; it would seem plausible that those most attracted to new active transport infrastructure would be those that are already active, or at least partially active. However, the evidence to support such an assertion for active transport infrastructure is limited[6].

Data on total demand for active transport infrastructure is also limited, including information on the physical activity status of users[7]. In the absence of this information, a number of assumptions need be made. These assumptions are based on similar work undertaken elsewhere, and accepted by the relevant transport authorities in those jurisdictions. Therefore, the basis upon which these assumptions are made on the basis that further research is warranted to refine the unit values.

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[6] An example where this is currently being attempted is Cambridge in the UK for a public transport and active transport project is described by Ogilvie et al. (2010). Results from that study are unlikely to available for several years.

[7] We are not aware of any prospective studies, either from Queensland or elsewhere, on the health impacts of infrastructure projects. There may be useful information from the health sector on the impact of behaviour change programs, which would be a useful avenue of further work.

The approach described here is consistent with Genter et al. (2008), which developed a method for calculating the active transport health in New Zealand and which was subsequently adopted (with modification) in the New Zealand Economic Evaluation Manual (NZTA, 2010) and by the Victorian Department of Transport (2010). The methodology is as follows:

- assume the trip kilometres on the new infrastructure would be equal to the proportion of the population in each physical activity category (sedentary, insufficiently active and sufficiently active),
- assume that sufficiently active means 30 minutes of physical activity on at least 5 days per week as per the NPAS guidelines (assuming walking at 5 km/hr this corresponds to 652 km per year),
- assume for sedentary individuals that, should they use the project, they would move from sedentary to sufficiently active, and that this shift would be achieved entirely as a result of using the project[8],
- assume that insufficiently active individuals currently achieve 10 minutes activity per day, and that if they were to use the project they would increase their activity sufficiently to move into the sufficiently active segment (at an additional 20 minutes per day over 5 days per week this implies an additional 435 km per year),
- Genter et al. calculates, based on the relative risk ratios in Andersen et al. (2000), that the marginal benefit to insufficiently active individuals is 0.85,
- while Genter et al. assumes a marginal benefit to active individuals of 0.15, we have conservatively assumed no marginal benefit to active individuals (i.e. a weight of zero[9]).

These assumptions are applied in Table 3.5, giving a walking benefit of $1.68/km and cycling benefit of $1.12/km.

[8] It is conceivable that a sedentary person who starts to walk or cycle on the new active transport infrastructure would be catalysed into undertaking other physical activities also (‘spillover’ effects).

[9] This is consistent with the assumptions made by NZTA in adopting the Genter et al. values in the Economic Evaluation Manual (NZTA 2010).

■ Table 3.5: Calculation of weighted per km benefits (Genter method)

		Activity level			
		Sedentary	**Insufficiently active**	**Sufficiently active**	**Weighted benefit** [5]
A	Proportion [1]	11.8%	34.3%	53.9%	
B	Weight [2]	1.00	0.85	0.00	
C	Benefit [3]	$249.27	$622.40	$0.00	
D	Additional km	652 km	435 km	n/a	
E	Walking benefit per km	$0.38	$1.43	$0.00	**$1.68**
F	MET ratio [4]	2.67	2.67	2.67	
G	Cycling benefit per km	$0.25	$0.95	$0.00	**$1.12**

[1] Queensland Health (2010)

[2] LTNZ (2010), adapted from Genter et al. (2007) who in turn derived from RRs reported in Andersen et al. (2000)

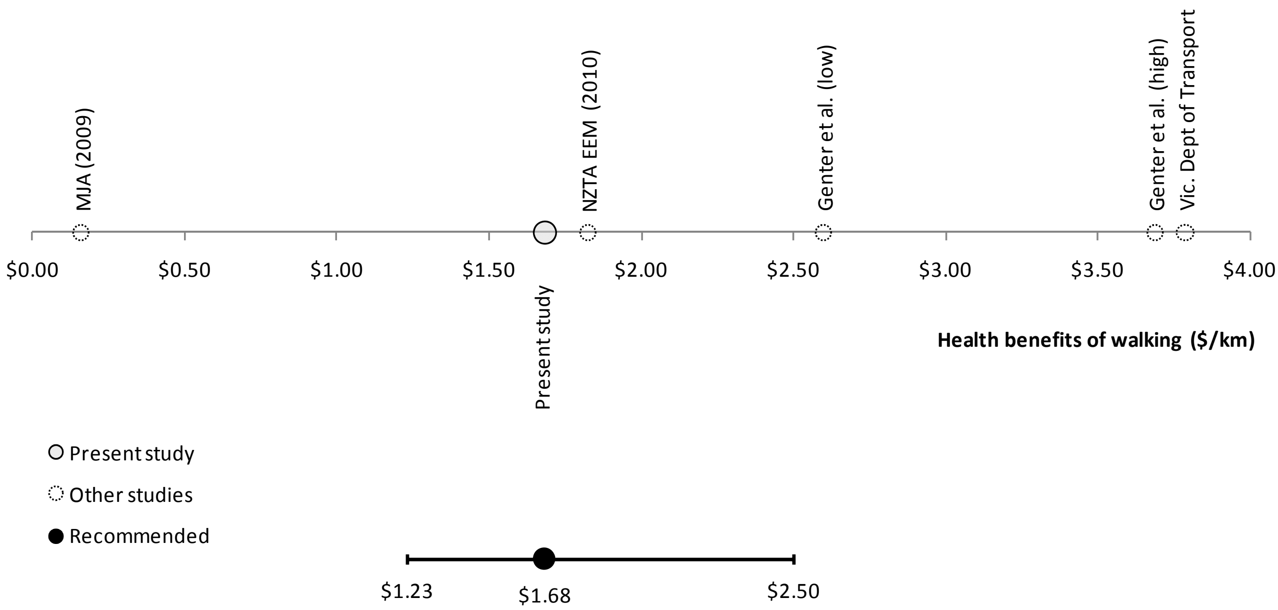
[3] The benefit per segment is the total benefit per inactive individual ($1,941 + $171) multiplied by the segment proportion (A) and weight (B).

[4] Ainsworth et al. (2000) reported metabolic rates for moderately vigorous cycling of 8 and walking of 3.

[5] The weighted benefit is the sum of the benefit in each activity level multiplied by the weight for that level.

A check on the plausibility of the health benefits is undertaken by comparing these with similar studies elsewhere. While there will invariably be much greater variation in these comparisons due to local factors and wide variation in methodologies such an approach can serve to provide reassurance about the validity of indentified parameters. These comparisons are presented in Figure 3.1 for walking and Figure 3.2 for cycling. These figures should be interpreted in conjunction with understanding the scope of each of these studies; for example, the RTA (2003) cycling benefit presented in Figure 3.2 is estimated solely for mortality due to heart disease. The present study estimate covers both mortality and morbidity, and falls at the lower end of studies which cover both these health components. This provides some reassurance that despite the assumptions made to determine these estimates, they fall within the range of existing estimates.

■ Figure 3.1: Comparison of health benefit unit values for walking ($/km, 2010 prices)



■ Figure 3.2: Comparison of health benefit unit values for cycling ($/km, 2010 prices)

Our recommended values are given in Table 3.6 and include sensitivity ranges covering the value of statistical life ranges (Table 2.5).

Table 3.6: Health benefits unit values (2010 prices)

Mode	Value	Sensitivity range	
Walking	$1.68/km	$1.23/km	$2.50/km
Cycling	$1.12/km	$0.82/km	$1.67/km

3.2.4 Ramping of health benefits

The health benefits that accrue from increased physical activity will not occur immediately as reduced costs to the health sector or the individual. Instead, the benefits will only become apparent over time. UK practice (UK Department of Transport, 2010) is to ramp up the benefits linearly over a five year period. By this method, the health benefits from an increase in active transport travel in year 0 will accrue to 20% of its value in year 0 and in each year thereafter through to year 4.

3.2.5 Absenteeism

In addition to reduced mortality and morbidity costs, there is evidence to suggest that an active and healthy population is also more productive due to reduced absenteeism. However, these productivity benefits have not been quantified within this study as the evidence remains incomplete (Genter et al., 2008). Although unquantified, this lends weight to adopting a health value towards the upper end of the range.

3.3 Injury costs

Whether increases in cycling and walking result in changes to the net injury costs to society depends upon a large number of factors, including:

- the nature of the infrastructure and its proximity to road traffic (particularly high speed traffic),
- whether the infrastructure is present for the majority of a trip or only part (in which there may be an elevated risk away from the project among new users),
- whether there is any destination switching, such as from longer car journeys to shorter active transport journeys, which may result in a higher per kilometre risk but lower overall risk (because of the shorter distance),
- the impact of ‘safety in numbers’ on risk,
- whether the user diverted from a higher risk to a lower risk mode, and
- the gender and age of the individual use.

The latter of these issues was noted as being particularly important by Stipdonk and Reurings (2010) in an analysis of exchanging short car trips for cycling in the Netherlands. They found that for all age and gender groups there would be an elevated injury risk, except for 18-19 year old males (who have a very high casualty risk when driving). In practice, our understanding of the relative risks to each of these users groups is limited by a lack of data. However, what data is available can be used to develop an estimate of the injury costs. This estimate should be refined with further research, as described further in Section 8.

3.3.1 Safety in numbers

There is an argument that injury rates to cyclists and pedestrians will decline as the levels of participation increase. This is not to say that overall injuries will decrease, but rather that the risk measured relative to exposure (time or distance) will decrease. Such an argument is based on empirical evidence, both cross sectional and longitudinal, and is supported by experimental psychology, which suggests that people recognise and respondent more quickly to frequent events (Austroads, 2010). Cavill et al. (2007) suggest the effect is attributable to three discrete effects:

- the safety in numbers effect, whereby more cyclists imply more visibility to road users,
- road user familiarisation, which proposes that as participation in cycling increases, road users are not only more likely to be a cyclist, but also have more awareness and understanding of sharing common roads and infrastructure, and
- safety with experience, which proposes that as individual's cycle more, their level of experience increases, resulting in a reduction in crashes and injury.

Jacobsen (2003) presented evidence from Europe and the USA of both the longitudinal and cross-sectional impacts of cycling and walking demand on injury risk. He concluded that if pedestrian and cyclist demand was to double (i.e. increase by 100%) there would be only a 34% increase in injuries. This is not inconsistent with crash prediction models developed in Australia and New Zealand by Austroads (2011), where it was found that at intersection approaches doubling the number of cyclists increased the number of injuries by around 20%.

What is less clear is whether there is a *causal* link between pedestrian and cyclist demand and safety. Instead, it is plausible that there is correlation but not direct causation. This is because increasing active transport demand will probably be achieved through the provision of segregated infrastructure and complementary measures such as speed limit reductions, which are likely to have a direct impact on safety (and demand). As such, our view is that it should be the relative risk of the specific active transport project, relative to the *status quo*, that should be considered first. It may then be argued there is some supplementary safety in numbers benefit if the likely change in active transport demand is significant, but this should be evaluated only as a sensitivity check.

3.3.2 Injury risk

Both cycling and walking, at least in urban areas, exposes users to a greater risk of fatality or serious injury than travelling by car or public transport. The rate of fatal, serious and other injuries per million person kilometres travelled in Queensland is higher for cyclists and pedestrians than for private vehicles[10]. This is shown in Table 3.7.

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[10] Measuring risk on a per kilometre travelled basis will bias risk comparisons against active transport modes, as they are typically slower than motorised modes (and so 'exposed' for a longer period over a given distance). Where exposure is measured in time units any elevated risk of active transport relative to motorised transport will be diminished. Further, if shifting to active transport results in destination shifting then the net risk may *reduce*. For example, a parent driving their child 5 km to school may present a greater risk to that child than a 1 km walk or ride to school.

■ Table 3.7: Injury risk by mode and severity

Mode	Kilometres travelled per annum	Injuries [3]			Risk of injury (per million km)		
		Fatal	Serious	Other	Fatal	Serious	Other
Car	40,240.2 [1]	225	4,580	11,285	0.0056	0.1138	0.2804
Cycling	292.5 [2]	9	287	500	0.0296	0.9800	1.7104
Walking	808.6 [2]	39	414	383	0.0486	0.5120	0.4736

[1] *Survey of Motor Vehicle Use, 12 months ended 31 Oct 2007*, ABS Cat. No. 9208.0 provides vehicle km, have estimated person km by assuming an average vehicle occupancy of 1.30.
[2] *SEQTS 2009* expanded to the Queensland population (this assumes cycling and walking rates are the same in SEQ and the rest of Queensland).
[3] Average of 2006-2009 Police reported injuries.

Austroads (2008) provide costs of road crashes based on severity and divided into human, vehicle and general costs[11].

■ Table 3.8: Average casualty costs by severity and cost component (2010 prices, from Austroads (2008))[12]

	Severity		
	Fatal	Serious	Other
Human costs	$1,672,308	$280,475	$6,135
Vehicle costs	$14,097	$11,879	$10,945
General costs	$124,758	$143,239	$230
Total	*$1,811,164*	*$435,593*	*$17,310*

The average cost per kilometre travelled was determined from Table 3.7 and Table 3.8 and are presented in Table 3.9. The injury cost is $0.37/km for cycling and $0.24/km for walking, or 5.6 and 3.7 times greater than travelling by car.

■ Table 3.9: Injury cost per kilometre travelled by mode and severity (2010 prices)

	Severity			
	Fatal	Serious	Other	All
Car	$0.0101	$0.0496	$0.0049	$0.0646
Bicycle	$0.0500	$0.2865	$0.0292	$0.3657
Walk	$0.0820	$0.1497	$0.0079	$0.2396

Car costs are human, vehicle and general costs. For cycling and walking only human and general costs are included.

[11] General costs are travel delays, insurance administration, police, property and fire related costs. The first two of these make up the majority of these costs.

[12] The Austroads method uses a human capital approach to estimate VoSL, which is significantly lower than the willingness-to-pay measure used to estimate health benefits. While internally inconsistent, such an approach is consistent with current Queensland road safety appraisal practice.

Table 3.9 implies that the injury cost of travelling by car is $0.06/km, comparable with current Austroads guidelines (Austroads, 2008) and similar calculations undertaken in NSW (PwC/SKM, 2010). The safety cost of travelling by bicycle is $0.37/km. This implies that a person switching from car to bike incurs an *additional* cost of $0.31/km ($0.37 - $0.06).

For public transport there is only very limited and dated information available, and none specific to Queensland. However, it is likely the risk of travel by public transport is very low. ATSB (2005) estimated the fatality rate (measured per million km) for bus to be 0.19 and rail 0.24, compared to a car driver rate of 0.99 fatalities per million km. Assuming, somewhat arbitrarily, that 80% of PT kilometres in Queensland are by bus the average PT fatality risk would be 0.20 deaths per million km; this equates to a relative risk of 0.20 relative to car driving. The resulting injury cost (assuming the severity split is the same as for car travel) is around $0.0129/km.

Table 3.10: Injury unit values (2010 prices)

Mode	Value
Cycling	-$0.37/km
Walking	-$0.24/km
Car [1]	-$0.06/km
Public transport [1]	-$0.01/km

[1] Required to estimate the marginal risk of users who divert from these modes to active transport.

3.3.3 Adjustments for facility type

In addition to accounting for the relative risk of shifting from car or public transport to active transport, it is necessary to consider how the project risk profile for walking and cycling compares with the *status quo*. In other words, to estimate whether the new project presents an equal, elevated or decreased risk per kilometre travelled compared with the current alternative(s). In many cases we may expect the relative risk to improve[13], particularly if the project is a shared path or cycleway where the alternative was a mixed traffic road.

There is very little information available on the relative risks of walking and riding on different types of routes, and no information from Australia[14]. What is known is that common perceptions do not appear to be supported by what limited evidence is available. For example, a significant proportion of all cyclist injuries occur away from roadways. QISU (2005) analysed hospital emergency department data and found that just over half (55%) of cyclist emergency department presentations involved riding on road and that only 6 to 8% involved a collision with a vehicle. Furthermore, they found that 10% of child and 6% of

[13] Indeed, this may be a major project objective.

[14] Although we note there is a study currently underway in NSW which should provide useful Australian insights into the risks of riding on different types of facilty.

adult injuries occurred on footpaths, and a further 7% of child and 8% of adult injuries occurred on bicycle paths. It is noted however that the injury severity was significantly greater for crashes which occurred on roadways and with vehicles.

In the absence of exposure data (i.e. the number of kilometres ridden and walked on different types of facility) it is not possible to convert these injury frequencies into risks. However, there have been a few studies overseas that have attempted to develop relative risks based on self-reports of travel and injuries. Three of these studies provide data most pertinent to this analysis:

- Lusk et al. (2011) found that the relative risk of bi-directional cycleways running alongside roadways in Montreal was 0.72 compared with riding on equivalent roads without cycling facilities.
- Päsanen and Räsänan (1999) found in Helsinki that the relative risk of riding on cycleways directly alongside roadways was 1.24, cycleways away from roadways 0.31 and on footpaths of 1.80 compared with riding on the road.
- Reynolds et al. (2009) reviewed studies from North America and Europe on cycling infrastructure and concluded on the basis of five North American studies that the relative risk of riding on-road in bicycle lanes compared with mixed traffic was around 0.50.

Given this limited evidence, the following approach has been adopted to adjusting the injury risk:

- assume relative risks of cycling relative to a roadway with no facility are 0.5 for on-road bicycle lanes, 0.3 for off-road paths and 1.80 for footpaths,
- assume current cycling kilometres are 60% on road with no facilities, 10% on-road with lanes or bicycle awareness zone symbols, 20% off-road on paths or in parks and 10% on footpaths[15],
- estimate a typical trip length for the corridor, and the proportion that will occur on the project (in order to account for travel that will occur away from the project),
- calculate a distance-weighted ‘risk index' for the *status quo* and project options, and
- calculate the relative risk as the ratio of the project risk index to *status quo* risk index.

For the standard assumptions above, and assuming (for example) the project is a 5 km shared path that would provide an alternative to cycling on-road, the relative risk would be 0.669 (i.e. a risk reduction of 33%).

3.3.4 Application within the economic appraisal

There are two further, very important factors to consider when calculating changes in injury costs. These have to be undertaken on a project specific basis as the unit value should change to reflect project nuances. While existing cyclists who divert to a new, safer route are accounted for in the above methodology the safety benefits to other road users of diverting a car user to cycling or walking is not considered. It would be expected that a car user who instead chooses to cycle or walk would represent a lower risk to other road users,

[15] These estimates will be corridor dependent, and should be adjusted by the proponent for the study area.

and so present an additional benefit to society. This idea has been explored empirically by Elvik (2009) but there is a paucity of data on how strong such an effect may be.

A second example that highlights the importance of considering the different user groups and nature of the infrastructure would be active transport infrastructure which eliminates, or properly delineates, vehicle and cyclist interaction at intersections. Schramm (2008) estimates that 54 per cent of accidents in Queensland occur at intersections. Hence, eliminating interaction at intersections along the route would reduce the exposure to injury for cyclists diverting from car by 54 per cent, lowering their injury cost. It would also reduce the exposure of existing cyclist, improving their safety and generating a benefit.

These examples underscore the importance of considering project specific nuances and adjusting the economic parameter values to reflect these.

3.4 Vehicle operating costs

3.4.1 Private car travel

A new active transport project may attract current car drivers and passengers to walk or cycle instead. This substitution would offer direct user savings in avoided vehicle operating costs (VOCs), as well as non-user benefits such as congestion, reduced emissions and noise.

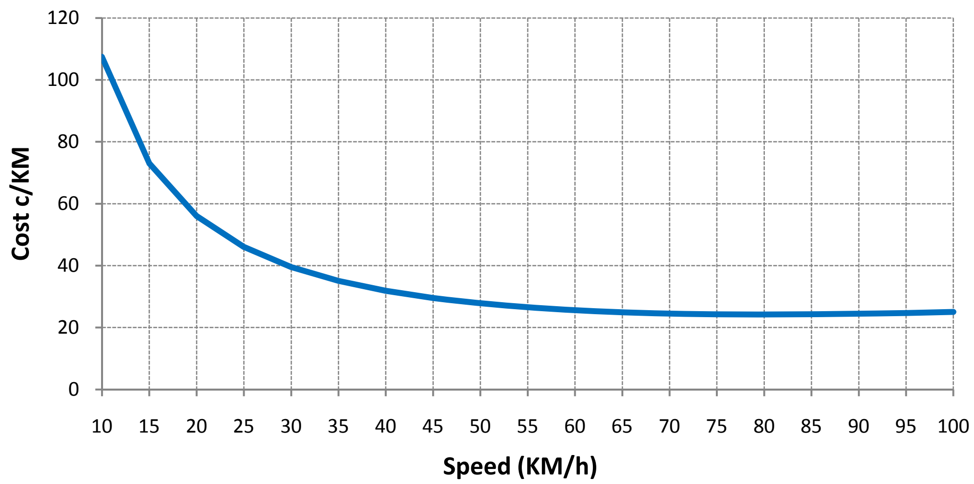
VOCs are a function of the length of a journey, traffic volume, driver behaviour (including speed), vehicle type, road condition (surface roughness) and characteristics (i.e. gradient and curvature). Bearing this in mind, total VOCs are comprised of:

- basic running costs (fixed and operational) of the vehicle, such as depreciation, fuel, oil, tyres, repairs and maintenance;
- additional running costs due to road surface;
- additional running costs due to any significant speed fluctuations from free flow speed; and
- additional fuel costs due to stopping, such as queuing at traffic signals.

3.4.2 VOC parameters

Austroads (2008) provides an urban journey speed VOC model which underpins the VOC assumptions used in road and multimodal appraisals in Australian jurisdictions. Austroads also publishes the coefficients for vehicle types and road type to populate this model; with average all day link speeds left as a project specific input to ensure that the calculated cost reflects the nature of the project. As part of this guidance, coefficients calculated specifically for Brisbane are published. Based upon a vehicle operating cost model for at grade urban roads, all day average link speeds and Brisbane specific at grade road coefficients, the estimated VOCs are shown below in Figure 3.3. This calculation implies a cost of $0.3185/km at an assumed average all day link speed of 40 km/h.[16]

■ Figure 3.3: Brisbane car vehicle operating costs (2010 prices)



Source: Austroads, 2008. 2010 prices

In NSW, the RTA calculates VOC for a number of vehicle types on a number of road conditions. For urban appraisals, a stop start model is most appropriate. These calculations within this model take into consideration journey speeds, grades, pavements conditions, operating costs, depreciation and interest costs (RTA, 2009). These calculations indicate a VOC of $0.35/km (2010 prices) for new cars travelling at an average journey speed of 40 km/h.[17] For simplicity, the RTA also calculates a VOC weighted by all vehicle types, urban and rural road networks and vehicle composition, using an average speed of 40 km/h. This weighted VOC for all vehicle types is $0.32/km (2010 prices), lower than the urban stop start model results due to the lower VOCs which occur in regional areas, on freeways and at higher speeds.

It is recommended that the Austroads value, reflecting Brisbane specific coefficients, be used for the appraisal of active transport in Queensland. The average all day link speed used in the recommended parameter value below is assumed to be 35 km/h. If may be deemed necessary by proponents to calculate an alternate value that reflects the nuances of the project.

[16] This assumed speed of 40km/hour is used to allow for further comparison with the vehicle operating costs used in other jurisdictions. It is acknowledged that many average link speeds and network wide speeds are lower than 40km/hour, hence it is recommended that, where possible, project specific speeds be used in the calculation.

[17] As per RTA (2009). New cars will have a higher VOC under this model than used cars due to higher depreciation and interest costs. The comparable VOC for used private cars in $0.312/km, in 2010 prices.

Table 3.11: Recommended vehicle operating cost savings (2010 prices)

	Value
Vehicle operating cost savings	$0.35/km

The rationale behind the recommendation to use the Austroads methodology is:

- adopting a nationally consistent methodology, which is also consistent with the calculation of VOCs used in the appraisal for other transport projects,
- the ability to incorporate variables (coefficients) that have been estimated specifically for Brisbane; and
- Providing flexibility in the ability to adapt the VOC (using a defined set of input coefficients) if specific active transport appraisals need to reflect vehicle operating costs in different areas (rural vs. urban), different road types (urban at grade roads vs. freeways) or different average link speeds. Hence, if it is warranted, the VOC can be tailored to the specific project, while still ensuring consistency with the VOC methodology used on other appraisals.

3.4.3 The application of the VOC parameter within a transport appraisal

An important consideration in the application of this parameter within the economic appraisal is the difference between perceived and unperceived VOCs. A large component of VOC for private vehicles is perceived by users (such as fuel, etc). Hence, these costs already influence a user's behaviour and can be incorporated into the generalised trip costs which are used to determine a user's modal decision. If the demand model does capture this perceived component, then the reduction in perceived VOCs is theoretically captured in the change in consumer surplus.

Under this scenario, only the unperceived costs for the use of private vehicles (vehicle depreciation, tyres and major repairs etc), can be quantified as a standalone benefit line item as they are not reflected in a user's behavioural preference and hence, are not captured within a user's consumer surplus. However, these unperceived costs still reflect an economic resource cost to society and must therefore be accounted for. This is done by examining the difference between the full urban vehicle resource costs and the perceived costs to users.

For the purposes of these active transport appraisals it is assumed that the VOCs are not captured within the road users generalised trip cost and hence, the full perceived and unperceived components need to be quantified. These two components are captured within the recommended Austroads value.

Finally, it is noted that there is an argument that the price of fuel will undergo a real increase throughout the appraisal period, resulting in higher vehicle operating costs. This increase may be offset to some degree by the increasing fuel economy of vehicles. There is currently no agreed approach to forecasting vehicle operating costs in Australia; an agreed approach is necessary for projects to be compared on a like-for-like basis. In the absence of such guidance it is recommended that current vehicle operating costs be assumed into the future and the analyst consider a sensitivity test of higher operating costs (which should also be incorporated into the demand forecasts).

3.4.3.1 Public transport travel

While it is likely that active transport projects will result in a diversion of public transport trips to active transport, a clear link should be established as to whether this diversion exceeds a threshold which would alter the provision of public transport services. For example, diverting one bus user to active transport is very unlikely to alter the fixed nature of rail or total bus service kilometres (the key variable for which vehicle operating costs are measured).[18] Therefore, before reduced public transport VOCs are considered within active transport appraisals, the following points need be considered:

- The geographic and temporal distribution of public transport trips diverted to active transport needs to be considered. Depending upon the nature of the scheme, it is likely that the reduction in public transport trips is not concentrated on one discrete service, location in the corridor or specific time of day. Wider geographic and temporal distribution implies that the reduction of public transport trips occurs across a very large number of public transport services often spanning a number of transport corridors.

  Furthermore, the demand for active transport, and by association increases or decreases in public transport trips, is heavily influenced by seasonality and weather conditions. It could therefore be argued that no single service is likely to be affected by enough volume reduction to result in a change in level of public transport services (and hence change in service kilometres), despite the marginal reduction in the aggregate number of public transport trips. It is these service kilometres, rather than passenger trips, which is a key metric used in costing and planning of public transport services.
- Any additional public transport capacity may be re-dispersed within the existing network rather than being discontinued, effectively resulting in no net change to public transport kilometres travelled and operating cost. It should however be noted that under this circumstance other public transport users are likely to receive a benefit from increased service provision and increased capacity (hence a reduction in on-board crowding).

Appraisals which quantify changes in public transport operating costs (and changes in decongestion and external environmental costs) should ensure that these considerations have been addressed.

3.4.4 Parking cost savings

Bicycle parking takes considerably less space than car parking. Hence, users substituting a car trip for a bike trip potentially reduce the demand, and future infrastructure requirements, for car parking infrastructure.

[18] The fall in public transport fare revenue would also need to be considered. It is plausible that given public transport service kilometres are not expected to change, the reduction of farebox revenue associated with fewer PT trips would actually increase the magnitude of the Government subsidy required to run these services

The actual parking cost savings attributable to active transport depend on marginal impacts. In the short run, reduced car trips may simply result in unoccupied parking spaces, but many destinations have parking problems that decline if parking demand is reduced. Over the long run, reduced parking demand allows property owners to avoid expanding parking capacity, or existing parking supply can be rented, leased or converted to other uses.

The quantification of this cost saving is not underpinned by the same degree of academic studies or empirical evidence as other cost savings quantified within transport appraisal. Quantifying this cost would also be heavily reliant upon detailed demand, planning and commercial information given the 'lumpy' nature of car park investment. The RTA (2003) estimated parking user cost savings of $0.01 per bicycle kilometre. This represented the avoided cost of parking facility infrastructure and maintenance. Given the minimal costs of bicycle parking, this estimate may be assumed for all active transport, including walking. This value has been assumed comparable to potential parking cost savings within Queensland.

■ Table 3.12: Parking cost savings (2010 prices)

	Value
Parking cost savings	$0.016/km

3.5 Travel time

It is standard practice in transport appraisals to assume that travellers value travel time savings, and would be prepared to pay to make savings. This is likely to apply equally to utilitarian active transport trips – cyclists and pedestrians will almost invariably take the shortest path (all else being equal). This is not likely to be true for active transport trips where the travel itself is the purpose (for example, a recreational walk or ride). In such cases the concept of travel time savings is moot.

Values of travel time saving are best classified by purpose; business travel will be valued more highly because it represents a productivity loss and the traveller will often not have to incur the cost themselves (they will be borne by the employer). It is conservatively assumed here that all active transport travel would be for non-business purposes, giving a value of travel time of $12.72/hour using the Austroads (2008) values.

■ Table 3.13: Value of travel time savings (2010 prices)

	Value
Travel time savings	$12.72/hr

In application it is recommended that travel time savings are valued for existing active transport users and induced travel[19]. While there may be travel time savings to those who divert from public transport (and car, in some circumstances) to cycling these benefits should not be included. There are three reasons for this:

- If travel time savings are included, then so too should travel time disbenefits to those users who divert to active transport but suffer a travel time disbenefit[20].
- The approach does not incorporate all generalised costs of the non-active transport modes, nor are these likely to be included in a demand model. This is related to the point above; the risk is that the appraisal will be inconsistent with utility maximisation.
- It would be necessary to weight access and egress trip times (e.g. a bus-to-rail station trip that shifts instead to bicycle to rail station) to construct a generalised cost of travel for motorised modes in the base case.

In practice it is unlikely any demand model would incorporate detailed generalised costs as described above. Given this, and the complexity of doing so, it is prudent to exclude these travel time savings.

3.6 Non-user benefits (positive externalities)

Non-user benefits are those benefits which accrue to the wider community, not just users of the new active transport infrastructure. These are commonly referred to as external benefits or externalities. An external benefit (or positive externality) results when the action of one transport user imposes results in benefits to third parties at no cost to these parties. Or, in economic terms, the marginal benefit to the direct user doesn’t capture the true marginal benefit that their change in travel behaviour has on society. These external benefits are therefore measured as the difference between social resource costs and private resource costs. Examples include reduced air pollution, greenhouse gas emissions and noise pollution.

3.6.1 Road decongestion

There are two components in estimating the costs of congestion, including the economic social costs and the level of traffic demand from which the magnitude of social costs are derived. Costs estimated by Bureau of Transport and Regional Economics (BTRE 2007) include allowances for:

- extra travel time (above what would have been incurred had the vehicle been travelling under free flow conditions),
- extra time variability (where congestion results in more uncertain trip times leading to travellers having to allow for a greater amount of travel time),
- increased vehicle operating costs (including fuel consumption), and

[19] The rule of half applies to the benefits for induced trips.

[20] As discussed in Section 6.4, the problem here is that rational utility maximisation would dictate that users will only divert if they increase their utility. It is likely that by including travel time disbenefits without other benefits (most likely amenity) the approach will be inconsistent with economic theory.

- poorer air quality (with vehicles under congested conditions emitting higher rates of pollutants than under free flow conditions).

3.6.1.1 Traffic volume

These economic social congestion costs are most commonly expressed as a total cost, estimated by comparing the actual travel speeds and vehicle operating costs with those that occur in urban areas under 'free flow' conditions. Different vehicle types impose various costs to other road users and wider society. In order to quantify the costs of overall traffic, it is necessary to represent traffic volume in a single vehicle unit. Traffic volume in passenger car equivalent units (PCUs) weight vehicle kilometre travelled (VKT) in order to reflect the traffic-impedance value of each vehicle class. For example, typical weights versus a passenger car (equal to one), are two for rigid trucks and buses, and three for an articulated truck.

Growth in traffic volume for the period 1990 to 2020 in metropolitan areas is estimated by BTRE (2007). Variations in forecast city growth rates for VKT (accounting for high growth in Brisbane and Perth) are due mainly to variations in project population growth. It is expected that the growth in total traffic will be approximately linear but at different rates for each city over the period 1990 to 2020. Thus, the absolute volume of traffic (in PCU terms) added in the next 15 years is likely to be the same as was added over the previous 15 years.

3.6.1.2 Estimating incremental congestion costs

Congestion costs for Australian metropolitan areas can be estimated by examining the relationship between the total social cost of congestion and estimates of the VKT by PCU equivalent vehicles over the period from 1990 to 2020. While the absolute growth in social cost will rise with VKT (or equivalently volume of traffic) the most relevant information for evaluation purposes is the marginal social cost imposed per each additional PCU km.

Given that the social cost of congestion and PCU km are estimated yearly for the period 1990 to 2020, the marginal social cost can be estimated:

1. The change in social cost of congestion between two consecutive years represents the congestion cost imposed by the additional volume of vehicles and PCU km travelled over the period.

$$\Delta\, SC \;= SC_{t_1} - \; SC_{t_0}$$

$$\textit{where SC is the social cost of congestion}$$

2. The change in PCU km travelled between two consecutive years represents the additional traffic volume and corresponding increase in equivalent PCU km travelled over the period.

$$\Delta\, PCU\ km \;= PCU\ km_{t_1} - \; PCU\ km_{t_0}$$

$$\textit{where PCU km are the passenger equivalent km travelled}$$

3 Given that BTRE provides both estimated social costs of congestion and the PCU km travelled (or volume of traffic contributing to congestion) for each year between 1990 and 2020, the marginal social cost of congestion for each year can be calculated.[21] The ratio of change in social cost to change in PCU km travelled for the same period illustrates the marginal social cost imposed per PCU km travelled.

$$ISC = \frac{\Delta\, SC}{\Delta\, PCU\ km}$$

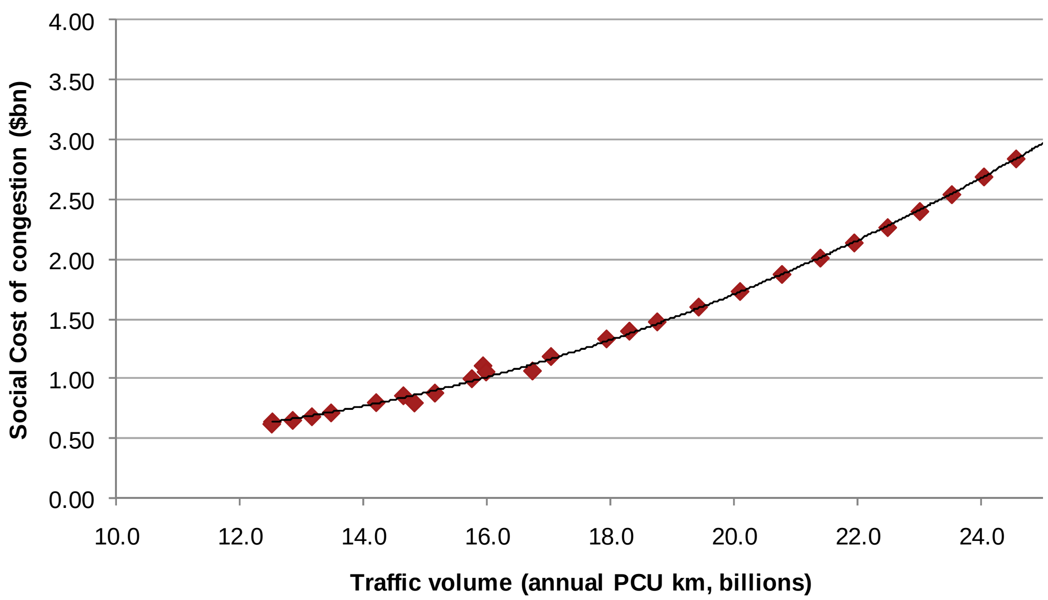
$$where\ ISC\ is\ the\ marginal\ social\ cost\ of\ congestion$$

A marginal cost estimation allows the congestion cost to change according to congestion levels. Using BTRE forecasts, the congestion cost per PCU km travelled approximately doubles for a 50% increase in traffic volume. The rate of increase in congestion costs also increases with the volume of traffic. Intuitively, this means that an additional car in crowded conditions will contribute more costs than an additional car in non-crowded conditions.

3.6.1.3 Brisbane specific congestion costs

The marginal social costs of congestion for Brisbane for the period 2004 to 2020 were estimated using the process described above. As shown in Figure 3.4, the social costs of congestion rise with traffic volume and the marginal social cost increases at higher levels of traffic.

■ Figure 3.4: Congestion cost estimates for Brisbane (2010 prices)

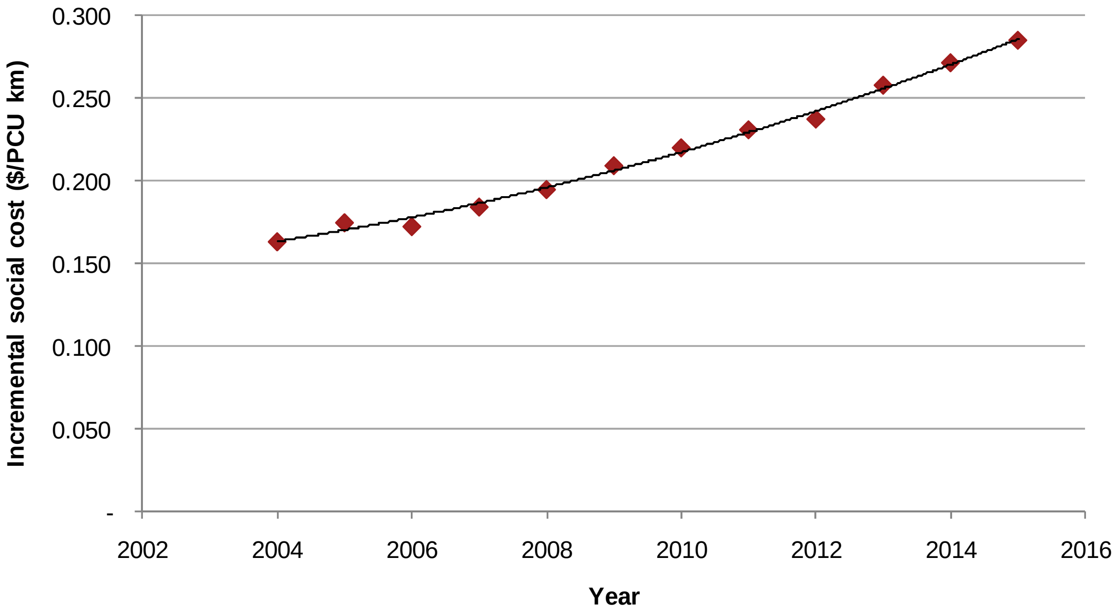


Due to the fact that both congestion costs and traffic volumes are based on yearly estimates, the function for marginal congestion costs can be converted into one that relates

[21] As there is high volatility in the estimates forecast by BTRE prior to 2003, the estimates of incremental social congestion costs have be based on BTRE estimates and forecasts from 2004 onwards.

to time. This is likely to be useful for annual congestion estimates and evaluation of transport initiatives (Figure 3.5).

- Figure 3.5 Marginal social congestion costs for Brisbane by traffic volume (2010 prices)



The marginal congestion costs in Brisbane during 2011 are estimated as $0.23 per PCU km.

3.6.1.4 Congestion costs by traffic flow

Given that the volume of traffic on the road network varies by time of day, the costs of congestion may change according to periods of busy, moderate and light traffic volume. Volume is used as a measure instead of defining a 'peak' time as it allows for measurement to reflect movement in the time of heavy traffic (according to season etc). Generally, the areas with highest congestion in heavy traffic volume periods will have the highest costs.

In order to estimate the variation in cost over time periods throughout the day, network-specific models are needed for the specific scenario or project being evaluated. In this case, the absence of a specific project means high level assumptions need to be adopted.

Currently, there are no Queensland Government endorsed congestion costs for various periods. However, the Australian Transport Council (ATC) quotes Victorian estimates as a basis for Australian time-variable congestion costs. Due to the generality of these costs, sensitivity analysis is needed in any appraisal.

The costs for Brisbane can be estimated based on Victorian time-variable congestion costs and an assumption of the portion of travel in busy, moderate and light periods.

■ Table 3.14: Congestion costs for heavy, moderate and light traffic flow (2010 prices)

Congestion level	Assumed portion of total travel (A)	Benefit rate per vehicle km (as per Victoria $2004) (B)	Cost relative to heavy traffic[22] (C=B/0.90)	Overall relative value for period (A*C)
Busy	30%	0.90	1.000	0.300
Moderate	35%	0.64	0.711	0.249
Light	35%	0.17	0.189	0.066
Total				*0.615*

Adapted from BTRE (2007).

The above suggests marginal congestion costs (2010 prices for Brisbane) of $0.337 per PCU km in busy flow conditions, $0.240 per PCU km in moderate flow conditions and $0.064 per PCU km in light flow conditions. These figures are shown in Table 3.15 below. [23]

■ Table 3.15 Period specific marginal congestion costs (2010 prices)

Congestion level	Assumed portion of total travel (A)	Period specific congestion costs ($/PCU-km)
Heavy (H)	30%	0.337
Moderate (M)	35%	0.240
Light (L)	35%	0.064

Active transport infrastructure and polices that result in a substitution of car trips for cycling or walking trips will lead to reductions in levels of congestion on the road network. Such reductions lead to improved average speeds, resulting in travel times and lower VOCs for remaining road users.[24] The method used in this appraisal for estimating decongestion benefits for motorists, as a result of car users switching to active transport, is to multiply the reduction in VKTs for car travel by a generalised parameter which represents the value of this decongestion.

[22] Relative ratios have been derived using the cost rates expressed by the ATC (2006) for Victoria using heavy traffic as the reference period. For example, the relative value for moderate traffic is 0.64/0.90=0.711.

[23] Calculated using the average congestion cost in 2011 ($0.23 per PCU-km), where 0.23= H*0.615, or H=0.337. Similarly, moderate traffic was calculated as M=0.23*(0.64/0.615)=0.24.

[24] Freed-up road space might in fact be taken up by new users, leaving congestion conditions unchanged. However, there are presumably benefits in these new road users making their trips otherwise they would not make them. Thus, there are either benefits to remaining road users with less congestion or increased benefits to new road users making the trip. Both benefits should, theoretically, be of equal or comparable magnitude. For the purposes of this study the quantification focuses on quantifying the benefits of decongestion.

Victoria and NSW transport agencies provide specific guidance on appropriate decongestion parameter values to use in transport appraisals. These provide a reference point from which to interpret the Brisbane specific findings.

Table 3.16: Survey of incremental congestion costs (2010 prices)

Jurisdiction	Value	Comments
NSW	$0.405/km	RailCorp (2010)
Victoria	$0.355/km	Based upon time of day specific congestion costs and estimates volumes occurring during these periods (Victorian Dept of Infrastructure, Default Appraisal Parameters (Excel s/sheet guidance).
Brisbane	$0.021/KM	Assuming 30% of traffic in heavy congestion, 35% in medium and 35% in light congestion.

The variance in incremental congestion costs across major cities is large. However, this level of variance broadly reflects the relative differences in congestion costs first identified in the BTRE paper. For example, the paper estimated the cost of congestion in Sydney in 2005 to be $3.5 billion, Melbourne $3.0 billion and Brisbane $1.2 billion.

3.6.2 Noise

While no mode of transport is entirely noise free, active transport is generally considered to be a virtually noiseless form of transport compared to motorised transport. Reduced noise (and all environmental externalities) stemming from reduced demand for buses and rail travel should satisfy the considerations discussed under vehicle operating costs and decongestion around the potential of marginal changes in marginal changes in public transport demand to influence provision of services.

Given the uncertainties about any reduction in noise attributable to marginal changes in public transport demand, we consider only the private car noise in this guidance. For this we adopt Austroads (2007), which recommends a unit value of $0.0082 per VKT which has been escalated to 2010 prices in Table 3.17. The Austroads guidance also provides bounds about which this value may be tested.

- Table 3.17: Noise benefits (2010 prices)

		Sensitivity range	
	Value	Low	High
Noise benefit	$0.091/km	$0.0065/km	$0.0117/km

3.6.3 Air quality

Active transport effectively produces no air pollution, aside from the very small increase in CO_2 emissions associated with an increase in metabolic rate. Even this very small increment is preferable to the form of CO_2 emissions from motorised forms of transport as it is produced from renewable sources (food) rather than from fossil fuels.

This compares to motor vehicles, which are a major contributor of air pollutants, accounting for more than 50% of the emissions of oxides of nitrogen (NOx), carbon monoxide (CO) and almost half the emissions of hydrocarbons in Australia each year (Austroads, 2000).

In urban areas, emissions reductions can be large because active transport trips are more likely to replace short, cold-start trips for which internal combustion engines have high emission rates. Hence, each 1% of automobile travel replaced by walking (or cycling) is estimated to decrease motor vehicle emissions by 2% to 4% (Victoria Transport Institute, 2004).

Austroads (2007) proposes a benefit from reduced air pollution of \$0.0245 per VKT, which has been indexed to 2010 prices below.

■ Table 3.18: Air quality benefits (2010 prices)

		Sensitivity range	
	Value	**Low**	**High**
Air quality	\$0.0281/km	\$0.0275/km	\$0.0288/km

3.6.4 Greenhouse gas emissions

Cycling and walking offer substantial potential to lower emissions in the passenger transport sector. There are three means by which greenhouse gas emissions from diverting car travel to active transport can reduce greenhouse gas emissions:

- substituting kilometres travelled in motor vehicles with active transport trips,
- reducing reliance upon cars (which have significant embedded emissions), and
- improving traffic flow through reducing congestion or improving roadspace management.

An average car in the Australia will emit around 0.23 kg of CO_2 per kilometre[25]. As a consequence, for each kilometre walked instead of being driven; a saving of approximately 0.23 kg of CO_2 can be achieved (excluding the additional contribution of the vehicles embedded energy).

Austroads (2007) recommend a value of \$0.02/km for cars, which implies a carbon price of around \$85/tonne. We have adopted this value as the recommended value.

[25] Based on a typical fuel economy of 10 L/100 km and a petrol CO_2 intensity of 2.3 kg/L.

■ Table 3.19: Greenhouse gas benefits (2010 prices)

	Value	Sensitivity range Low	Sensitivity range High
Greenhouse gas reduction	$0.0221/km	$0.0196/km	$0.0248/km

3.6.5 Infrastructure (roadway) maintenance savings

Depending on the extent of substitution, an increase in active transport has the potential to reduce road maintenance costs. The wear and tear on roads and associated infrastructure is small for active transport compared to vehicles.

The NSW RTA (2003) assumes that roadway cost savings associated with the provision of new cycleways are $0.033 per bicycle kilometre that is diverted from car. This assumption was informed by work undertaken by Austroads (1994). These assumptions hold true for all forms of active transport, including walking.

■ Table 3.20: Infrastructure (roadway) maintenance savings (2010 prices)

	Value
Infrastructure (roadway) maintenance savings	$0.052/km

3.6.6 Public transport crowding

Studies indicate that public transport passengers will be willing to pay for a reduction in crowding. Douglas Economics (2006) conducted surveys of train passengers to estimate the crowding cost associated with various degrees of crowding, from low crowding to a crush stand for 20 minutes or longer. Crowding cost estimates range from $0.02 per minute to $0.17 per minute (in 2003 prices) depending on the level of crowding.

Traditional rail and multi-modal transport appraisals do not include measures of willingness to pay for a reduction in crowding for public transport. This reduction in public transport crowding is not expect to be a major benefit in active transport projects. Given the practical difficulties often encountered when accurately trying to measure and qualify change in public transport crowding levels, it is recommended that this be treated as a qualitative benefit.

4 Diversion rates

The benefits of active transport projects will be highly dependent on who is attracted to use the project. The demand for a new active transport project will come from a combination of four groups:

- **reassignment**: existing active transport user who changes their route to use the new facility,
- **induced:** an all-new trip that occurs only because of the project (e.g. new recreational riding and walking trips that would not otherwise have occurred),
- **shift from car:** trips that would otherwise have been made by private car, and
- **shift from public transport:** trips that would otherwise have been made by public transport.

As shown in Table 4.1 only the health and injury benefits apply to all user groups.

■ Table 4.1: Benefits applied to each user group

	User Group			
Benefit	**Reassign**	**Induced**	**Shift from car**	**Shift from PT**
Health	●	●	●	●
Decongestion	—	—	●	—
Vehicle operating cost	—	—	●	—
Injury costs	●	●	●	●
Noise reduction	—	—	●	—
Air quality	—	—	●	—
Greenhouse gas emissions	—	—	●	—
Infra. (roadway) provision	—	—	●	—
Parking cost savings	—	—	●	—
Travel time savings	●	○	— [1]	— [1]

● Full benefits

○ Rule of half applies

— No benefit applied

[1] Excluded on the basis that these (dis)benefits may conflict with economic theory (utility maximisation) without a complete generalised cost specification on these modes.

The diversion rate can be estimated in one of two ways:

- it may be assumed that new active transport users will be attracted equally from all other modes, such that the diversions will be in proportion to the existing mode shares in the area or (better) along the corridor , or
- intercept surveys of users on existing and (ideally) recently opened active transport infrastructure to identify what mode(s) were previously used.

The former method may be incorrect if diverted active transport users are attracted at different rates for car and from public transport. However, there is currently very little empirical evidence to support this view.

In order to develop an improved understanding of diversion to active transport intercept surveys were conducted as part of this study, both on weekdays and weekends and at four locations:

- Go-Between Bridge,
- Normanby Cycleway and Pedestrian Link,
- Ted Smout Bridge, and
- Sir Leo Hielscher Bridge.

These intercept surveys provided an indication of the diversion rates that may be expected on active transport projects, both in inner city (where there are likely to be many route and public transport alternatives) and other regions (where there are likely to be few routes and limited public transport options). The survey method and results are discussed in detail in Appendix A. As a general guide, the data from these intercept surveys was used to derive indicative diversion rates as shown in Table 4.2. In all cases, it is anticipated that at least half of all demand for an active transport project would change their route or destination to use the project. In all cases the proportion of users who would divert from car or public transport are relatively small. This in turn has an impact on the benefits of active transport projects, as those benefits attributable to diversion from car (e.g. decongestion and emissions) will be relatively minor.

- Table 4.2: Suggested diversion rates by mode and project location

	TO...			
	Cyclist		Pedestrian	
FROM...	**Inner City**	**Other Areas**	**Inner City**	**Other Areas**
Car	10%	15%	5%	10%
Public transport	20%	0%	15%	0%
Reassign	65%	55%	70%	50%
Induced	5%	30%	10%	40%

5 Standard operating costs

Standard operating costs are indicative costs of the ongoing operation of a transport system, and are typically based either on a per vehicle or per person kilometre measure. Australian Transport Council and Austroads guidelines provide indicative standard operating costs for road and public transport infrastructure. No such guidelines currently exist for active transport infrastructure. However, the Australian Bicycle Council (2006) developed a whole-of-life model for off-road shared use paths taking into account the initial capital cost and recurring maintenance over an (assumed) 40 year life of these assets. This model has been adopted for use here, and the indicative costs per kilometre are provided for asphalt and concrete 3 m paths in Table 3.1.

■ Table 5.1: Operating costs for off-road bicycle paths

			Costs per km[3]			Average operating cost per bicycle-km
Material	**CBR[1]**	**Traffic[2]**	**Construction**	**Maintenance**	**Total**	
Asphalt	> 10%	Low	$46,000	$40,000	$86,000	$0.0137
" "	< 10%	Low	$61,000	$53,000	$114,000	$0.0182
" "	> 10%	Medium	$80,000	$60,000	$140,000	$0.0041
" "	< 10%	Medium	$95,000	$77,000	$172,000	$0.0052
Joint unreinf. conc.	> 10%	Low	$101,000	$6,000	$107,000	$0.0020
" "	< 10%	Low	$130,000	$6,000	$136,000	$0.0021
" "	> 10%	Medium	$190,000	$6,000	$196,000	$0.004
" "	< 10%	Medium	$198,000	$7,000	$205,000	$0.005
Reinf. conc.	< 10%	Medium	$297,000	$6,000	$303,000	$0.004

[1] Californian Bearing Ratio, a standard measure of sub-grade condition. A higher percentage indicates a more stable sub-grade (and so reduced cost).

[2] 'Low' and 'medium' traffic flows are not quantified by the ABC; for the purposes of estimating an average operating cost here we assume low refers to an AADT of 200 and medium to an AADT of 1000 cyclists.

[3] Net present value based on a 7% discount rate and 40 year appraisal period, 2010 prices.

The recurring (operating) costs vary from $0.004 per bicycle km for concrete paths to $0.0182 per bicycle km for asphalt paths with weak sub-grades. While these estimates are highly sensitive to the demand assumptions, they are much lower than the standard operating costs of motorised transport.

Public transport (heavy rail and bus) costs will vary greatly depending on the network. Indicative operating costs for rail and bus operations are provided in the NGTSM (ATC, 2006). These costs cover only short run operating costs most directly related to vehicle operation, namely:

- on-vehicle crew costs
- direct operating cost of the vehicle
- marginal infrastructure maintenance and operations costs
- overhead on operating cost
- profit margin

In order to compare with the average cost of active transport infrastructure it is necessary to convert these costs to units of passenger kilometres. In order to do this average train and bus speeds of 40 and 25 km/h respectively have been assumed. Further, at an average all-day load factor of around 30% average loads are estimated at 300 for rail and 15 for bus. These assumptions imply costs of around $0.221 per passenger km for bus and $0.093 for train. By comparison, the marginal operating cost for Perth's urban rail and bus services are $0.41 and $0.76, respectively. This wide range reflects the sensitivity to loading assumptions and how long run operating costs are handled. Irrespective, public transport operating costs per passenger km are at least fifty times greater than cycleways, increasing to at least 200 times greater for concrete paths (Table 3.2). It should be noted however that on a per-trip basis the differences would be somewhat smaller, as the average distance travelled by bus and particularly train will be longer than bicycle.

The physical damage done to a roadway pavement or structure by a vehicle is directly related to the axle loading to the power of four. This means that the damage incurred by a bicycle (axle loading roughly 35 kg) is about 1/160,000th of a car weighing 1,500 kg. However, even in the absence of vehicle traffic (either cyclists or motor vehicles) a pavement will deteriorate over time; it is this cost (and the comparatively low volumes) which lead to the relatively high operating cost for asphalt paths shown in Table 3.2.

- Table 5.2: Standard operating cost comparison

Mode	Average operating cost per passenger-km
Bicycle	
- concrete path	$0.0005[1]
- asphalt path	$0.0052[2]
Bus	$0.221 - $0.76[3]
Train	$0.093 - $0.41[3]
Car	$0.0194[4]

[1] 3 m concrete path with 1,000 cyclists per day on a soft sub-grade.

[2] 3 m asphalt path with 1,000 cyclists per day on a soft sub-grade.

[3] Lower bound is ATC (2006) standard cost converted to passenger-km while upper bound is from TransPerth (2011).

[4] RTA (2003) for average maintenance costs and assuming average vehicle occupancy of 1.3.

Operating costs are incorporated into the economic appraisal as disbenefits in accordance with the NGTSM guidelines.

6 Application of model

In this section we demonstrate the application of the benefits and costs described in previous sections to existing and proposed active transport projects in Brisbane. These projects have been selected by TMR and the capital costs have been provided by TMR. Operating costs were estimated according to the unit rates described in Section 5 and demand has been estimated from a number of sources, as summarised in Table 6.1.

Each project was run with the following assumptions:

- 30 year project life
- 7% discount rate
- 5% per annum arithmetic growth in cycling and walking demand
- 30% of car shifted demand would occur during busy, 35% during medium and 35% during light traffic periods
- +/-50% uncertainty on operating costs
- 60% of cycling travel in the study area is typically on-road without bicycle provision, 10% is on-road with bicycle lanes, 20% is off-road and 10% is on footpaths
- Walking trips would be for 45 minutes (3.75 km at 5 km/h)
- Average cycling trip length is 10 km
- No safety in numbers effect
- Cyclists using the project would otherwise have to travel on-road with no bicycle lanes

It is emphasised that the input assumptions used here are high level; as such, the resulting appraisal should be treated only as indicative of the method and not used as an assessment of the projects.

■ Table 6.1: Scenario assumptions

Project	Status	Capital cost ($m)	Op. cost (opening yr)	Demand (ADT, opening yr)		Diversion rates				Dist. on project [1]	Distance saved	
				Cyclists	Peds	From car	From PT	Reassign	Induced		Cyclists	Peds
Centenary Motorway	Existing	$2.35	$250	68	50	Cyclist: 10%	20%	65%	5%	5 km	0 km	0 km
(Wacol to Darra)						Ped: 5%	15%	70%	10%			
Darra to Springfield Transport	Existing	$18.00 [2]	$3,600	164	30	Cyclist: 25%	29%	9%	37%	5 km	0 km	0 km
Corridor						Ped: 0%	0%	50%	50%			
Dinmore to Goodna Transport	Existing	$65.00	$14,200	970	261	Cyclist: 5%	0%	61%	33%	5 km	0 km	0 km
Corridor						Ped: 8%	0%	52%	40%			
Houghton Highway Duplication	Existing	$22.00	$4,800	970	261	Cyclist: 5%	0%	61%	33%	2 km	0 km	0 km
(Ted Smout Bridge)						Ped: 8%	0%	52%	40%			
Gateway Upgrade Project	Existing	$36.00	$600	164	30	Cyclist: 25%	29%	9%	37%	2 km	2 km	2 km
						Ped: 0%	0%	50%	50%			
Normanby Cycleway and	Existing	$17.10	$800	440	228	Cyclist: 10%	17%	65%	10%	2 km	0.3 km	0.3 km
Pedestrian Link						Ped: 1%	3%	67%	29%			
Go-Between Bridge	Existing	$16.90[3] [3]	$1,000	1,079 [4]	495	Cyclist: 5%	5%	85%	5%	2 km	0.3 km	0.3 km
						Ped: 3%	4%	78%	15%			
Moreton Bay Rail link	Proposed	$50.00	$4,800	970	261	Cyclist: 5%	0%	61%	52%	5 km	0 km	0 km
						Ped: 8%	0%	33%	40%			
North Brisbane Cycleway	Proposed	$37.00	$17,200	3,500	261	Cyclist: 10%	20%	65%	5%	5 km	0 km	0 km
						Ped: 5%	15%	70%	10%			

[1] Distance cycled on the project by the average cyclist (this will not necessarily be the full length of the project).

[2] Assumes $1.5m/km costs over a project length of 12 km.

[3] Assume the active transport provision cost was 5% of the total project cost ($338m).

[4] The two hour manual count from the intercept survey on Wednesday 25 May was expanded using permanent bicycle counter data from Kurilpa Bridge from January to April 2011 (giving an expansion factor of 2.6). The same time period distribution was assumed for pedestrians. Weekend cyclist count based on a BCC survey from Sunday 11 July 2010 (1,968 cyclists).

[6] Manual counts from site U18A – south of Endeavour Road during March 2010.

The distribution of the BCR and breakdown of the project benefits are provided for each project in the following sections. The summary data for each project is summarised in Table 6.2.

- Table 6.2: Summary of scenarios

Project	BCR [1]	Likelihood BCR < 1.0	NPV	Benefits [2]	Costs [2]
Centenary Motorway (Wacol to Darra)	1.0 (0.5 – 1.6)	44.7%	$0.1m (-$0.9m-$1.1m)	$2.0m	$1.9m
Darra to Springfield Transport Corridor	0.7 (0.2 – 1.1)	91.3%	-$5.0m (-$11.1m - $1.0m)	$9.7m	$14.7m
Dinmore to Goodna Transport Corridor	0.5 (0.2 – 0.8)	99.8%	-$27.8m (-$43.4m - -$12.3m)	$25.4m	$53.1m
Houghton Highway Duplication (Ted Smout Br.)	1.3 (0.4 – 2.2)	27.6%	$5.7m (-$10.0m - $21.3m)	$23.8m	$18.0m
Gateway Upgrade Project	0.3 (0.1 – 0.5)	100.0%	-$19.6m (-$25.5m - -$13.8m)	$9.8m	$29.4m
Normanby Cycleway and Pedestrian Link	0.8 (0.4 – 1.3)	72.0%	-$2.2m (-$8.2m - $3.9m)	$11.8m	$14.0m
Go-Between Bridge	1.0 (0.6 – 1.4)	47.4%	$0.2m (-$5.5m - $5.9m)	$14.0m	$13.8m
Moreton Bay Rail link	0.6 (0.2 – 1.0)	95.3%	-$15.4m (-$31.0m - -$0.2m)	$25.5m	$40.9m
North Brisbane Cycleway	2.4 (0.9 – 3.9)	6.2%	$43.1m (-$2.8m - $89.5m)	$73.6m	$30.5m

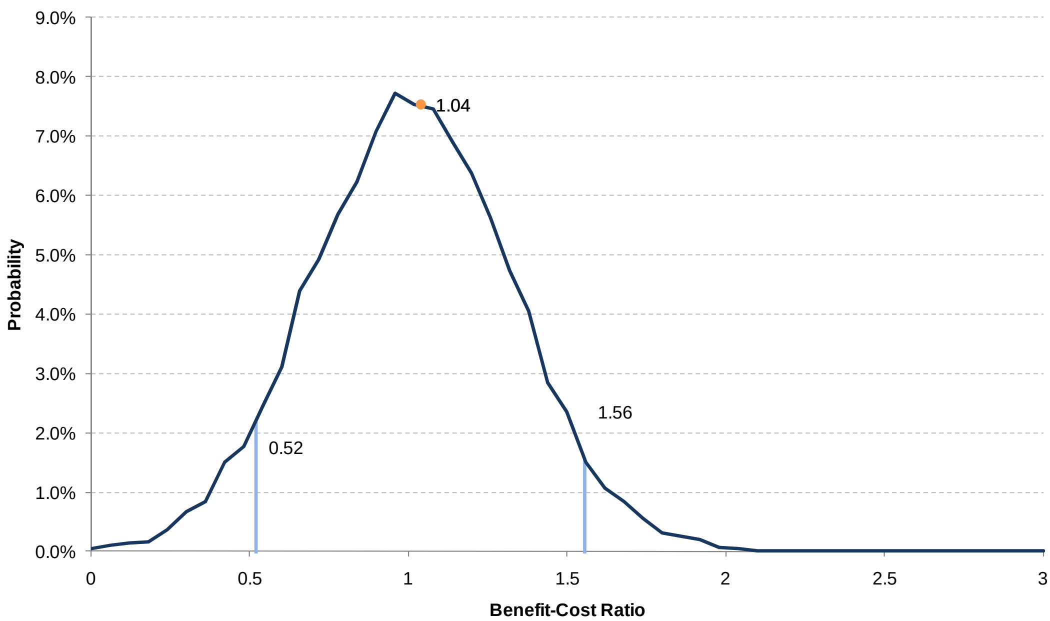
[1] 95% confidence interval in brackets.
[2] Discounted at 7%.

The BCRs range from 0.3 (Gateway Upgrade Project) to 2.4 (North Brisbane Cycleway). However, it is re-emphasised that these outcomes are strongly related to the input assumptions, and particularly to assumptions around capital costs and demand.

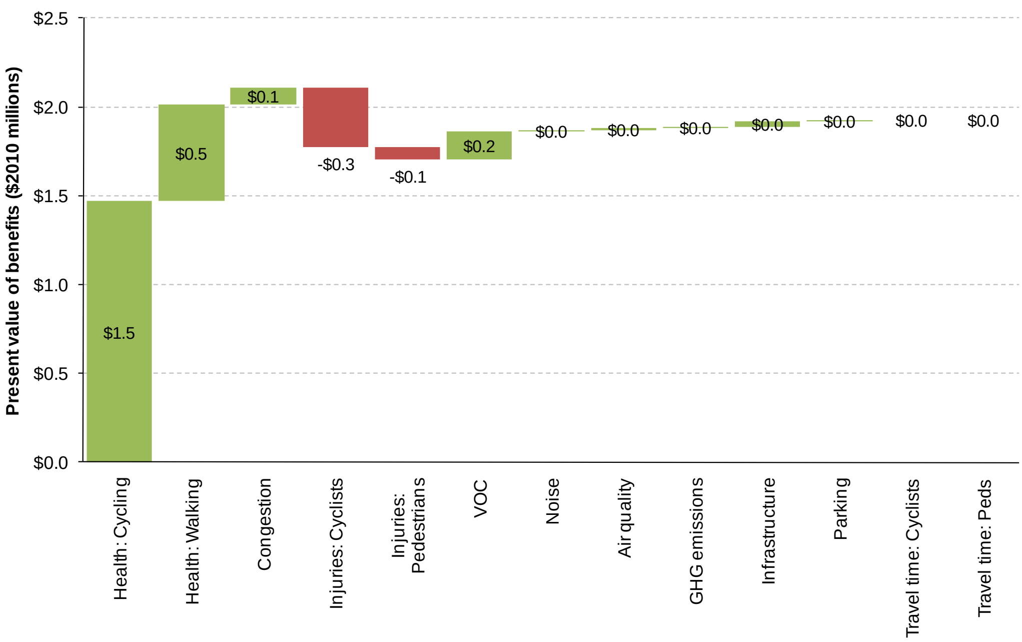
6.1.1 Centenary Motorway (Wacol to Darra)

The Centenary Motorway project is forecast to produce a BCR of around 1.0, with 95% likelihood that the BCR will lie in the range from 0.5 to 1.6 (Figure 6.1). Of the discounted benefits of $2m, around $1.5m is attributable to health benefits to cyclists and a further $0.5m to health benefits to pedestrians (Figure 6.1). Injury costs amount to around $0.3m for cyclists and $0.1m for pedestrians, indicating that the health benefits significantly exceed the injury costs. Of the $1.5m in health benefits to cyclists, $0.4m is attributable to car users who shift to cycling, while $0.8 is due to public transport users who shift to cycling. There are no benefits to existing cyclists who change route to use the project (as there is assumed to be no change in distance), and all-new cycling trips amount to $0.2m of health benefit.

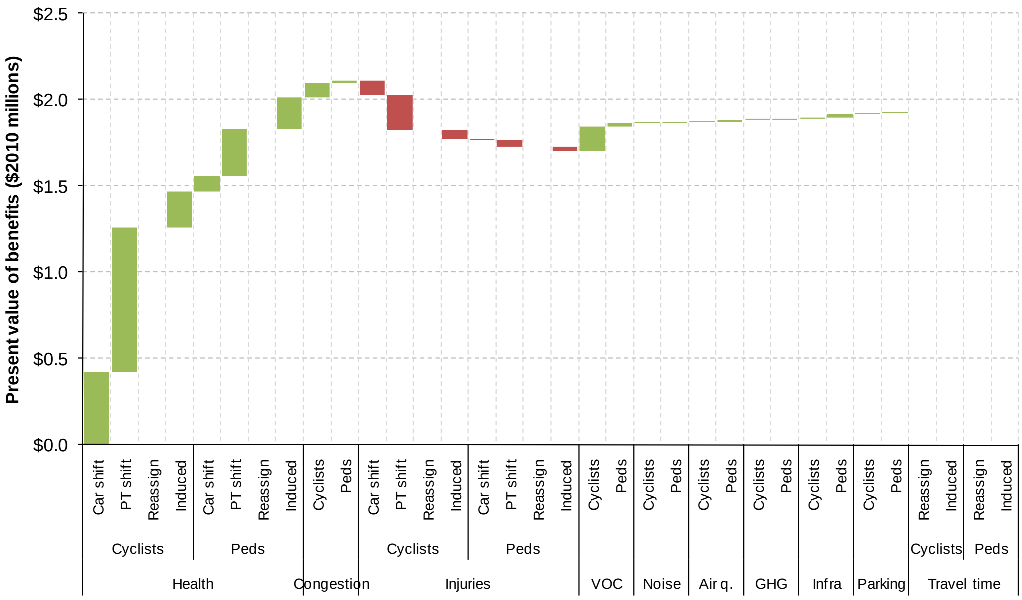
- Figure 6.1: Benefit-cost ratio distribution (Centenary Motorway)



- Figure 6.2: Summary breakdown of benefits (Centenary Motorway)



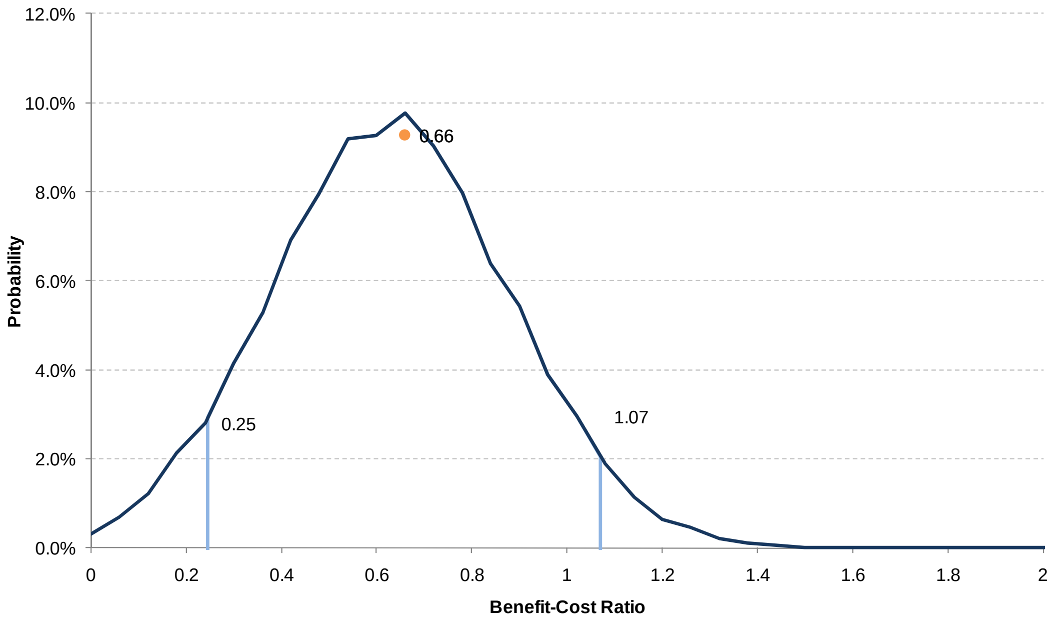
■ Figure 6.3: Detailed breakdown of benefits (Centenary Motorway)



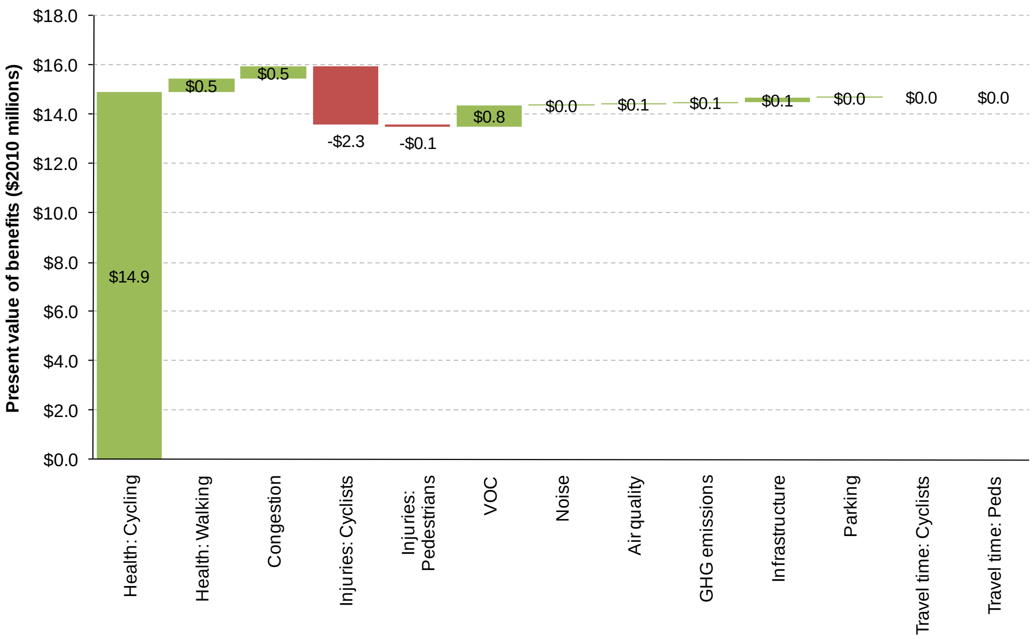
6.2 Darra to Springfield motorway corridor

The Darra to Springfield motorway project is estimated to have a BCR of around 0.7, with a 95% likelihood that the BCR falls in the range from 0.3 to 1.1 (Figure 6.4). There are assumed to be very few pedestrian trips per day in the opening year (30) compared with cycling trips (164), which means that most benefits are due to cyclist health (Figure 6.5). For the BCR to reach 1.0 either the number of cyclist trips in opening year would need be 250 per day, or the number of walking trips would need increase to around 400 per day.

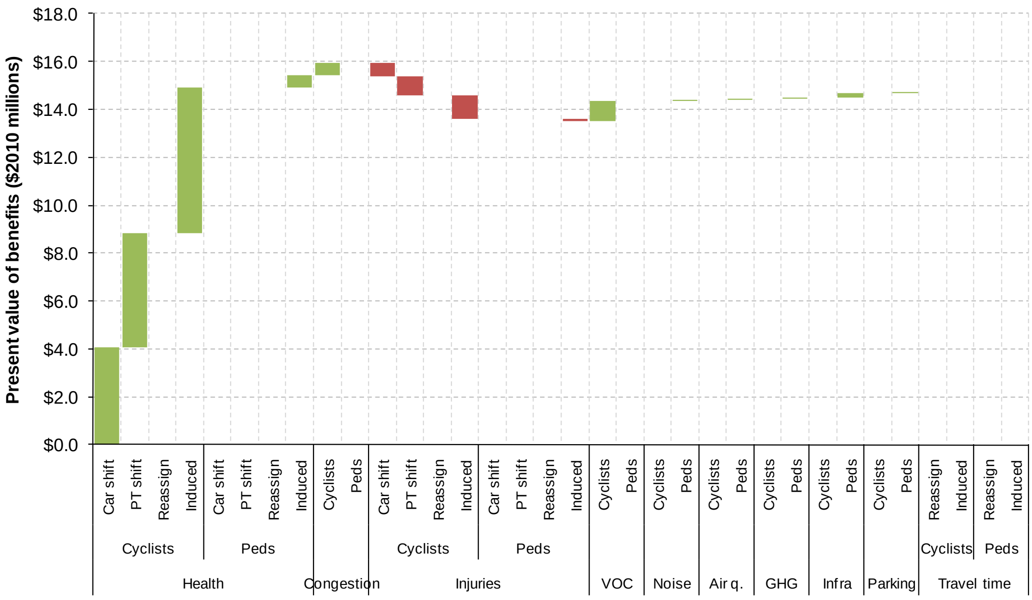
- Figure 6.4: Benefit-cost ratio distribution (Darra to Springfield motorway corridor)



- Figure 6.5: Summary breakdown of benefits (Darra to Springfield motorway corridor)



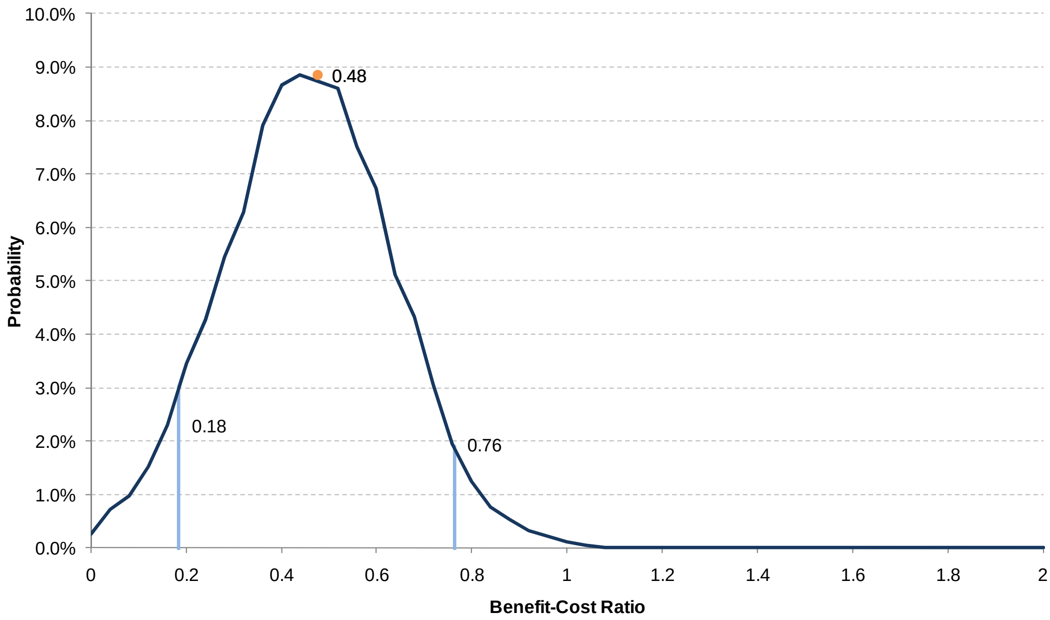
■ Figure 6.6: Detailed breakdown of benefits (Darra to Springfield motorway corridor)



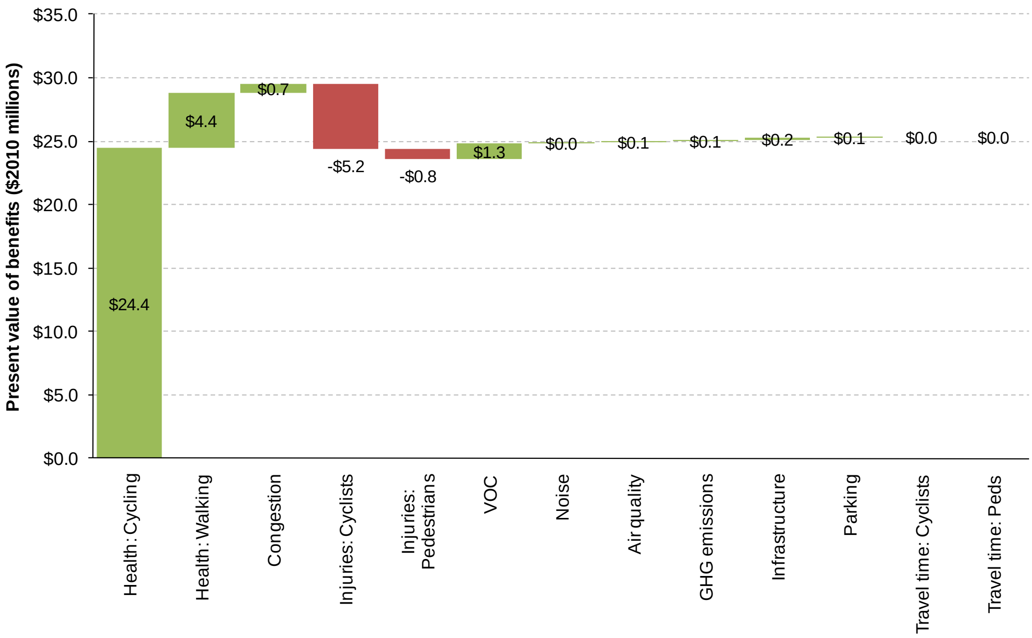
6.3 Dinmore to Goodna transport corridor

The best estimate of the BCR for the Dinmore to Goodna link is around 0.5, with a 95% likelihood of the BCR falling in the range 0.2 to 0.8 (Figure 6.7). Of the net benefit of around $25.4m, almost all is attributable to health benefits to cyclists and pedestrians (Figure 6.9). For the project to have a BCR of 1.0 the number of cycling trips per day in the opening year would need to increase from the assumed 970 trips/day to around 2,300 trips/day. Alternatively, the number of pedestrian trips would need increase in the opening year from 261 trips/day to 2,000 trips/day.

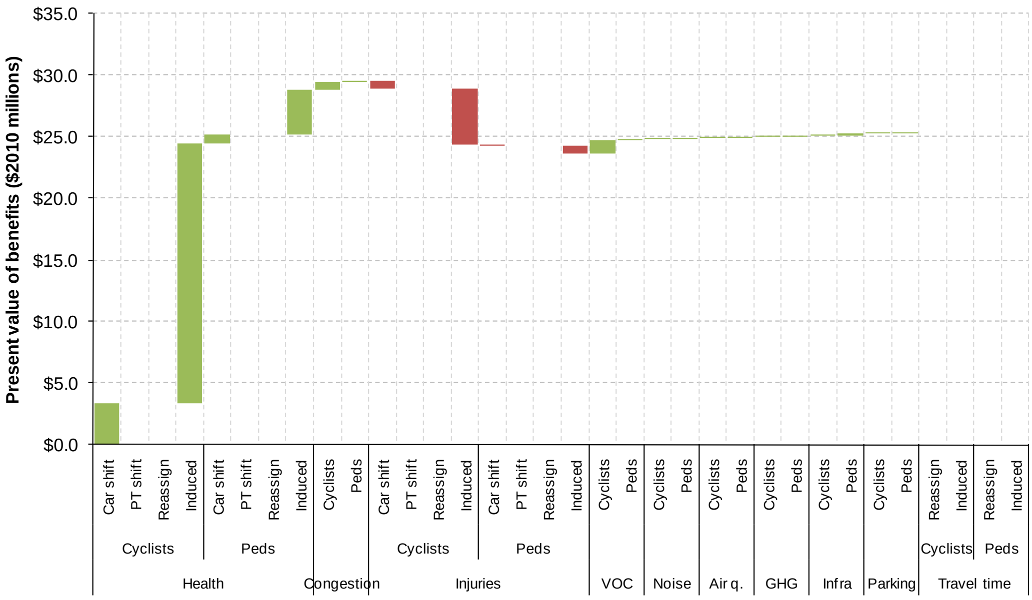
■ Figure 6.7: Benefit-cost distribution (Dinmore to Goodna transport corridor)



■ Figure 6.8: Summary breakdown of benefits (Dinmore to Goodna transport corridor)



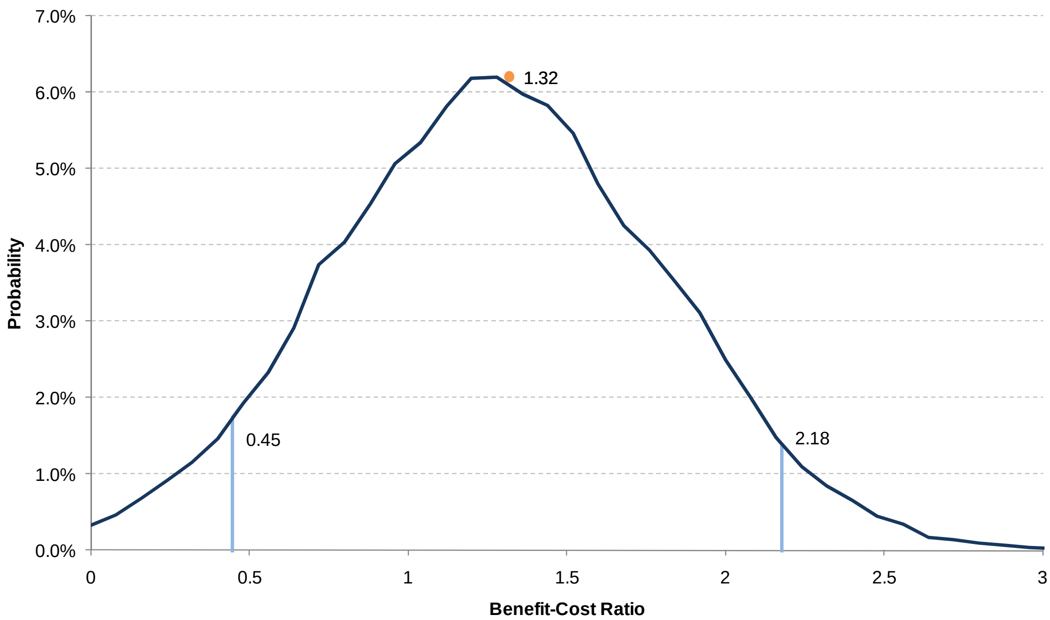
■ Figure 6.9: Detailed breakdown of benefits (Dinmore to Goodna transport corridor)



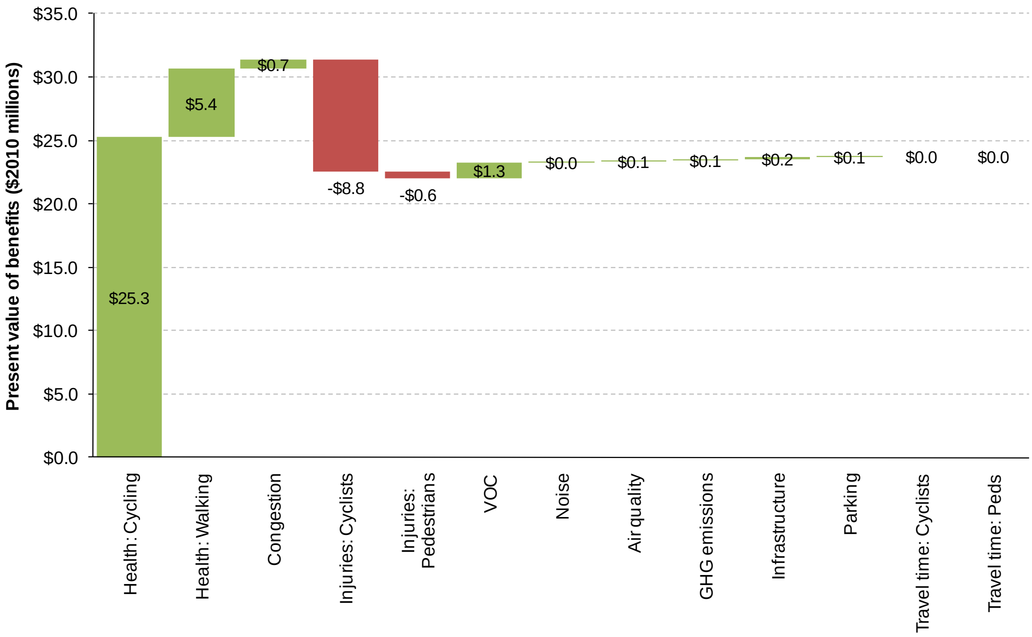
6.4 Houghton Highway duplication

The Houghton Highway duplication at Ted Smout Bridge produces a BCR of around 0.9, with a 95% likelihood of the BCR falling in the range from 0.4 to 1.4 (Figure 6.10).

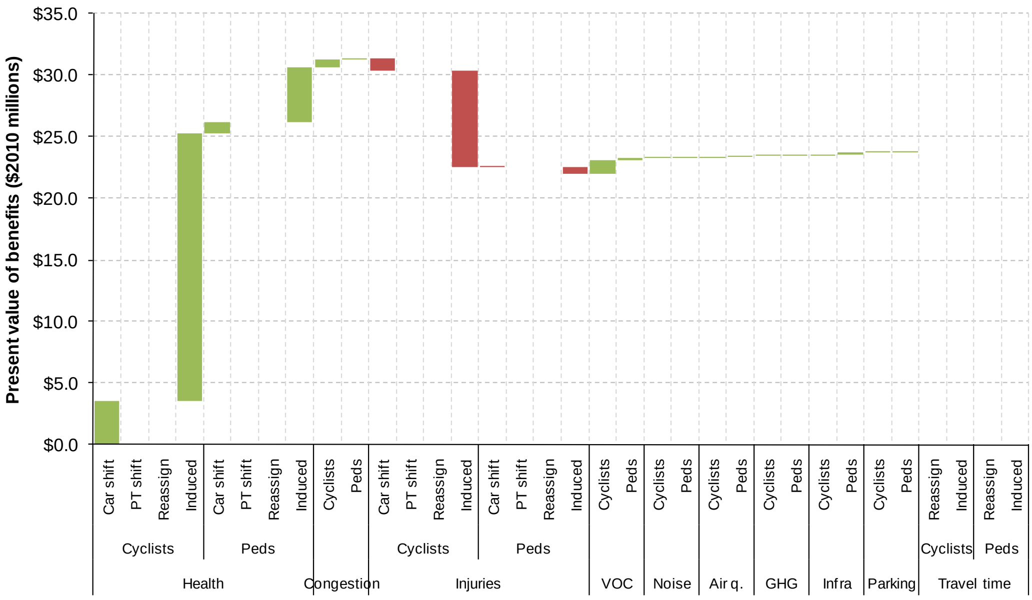
■ Figure 6.10: Benefit-cost ration distribution (Houghton Highway duplication)



- Figure 6.11: Summary breakdown of benefits (Houghton Highway duplication)



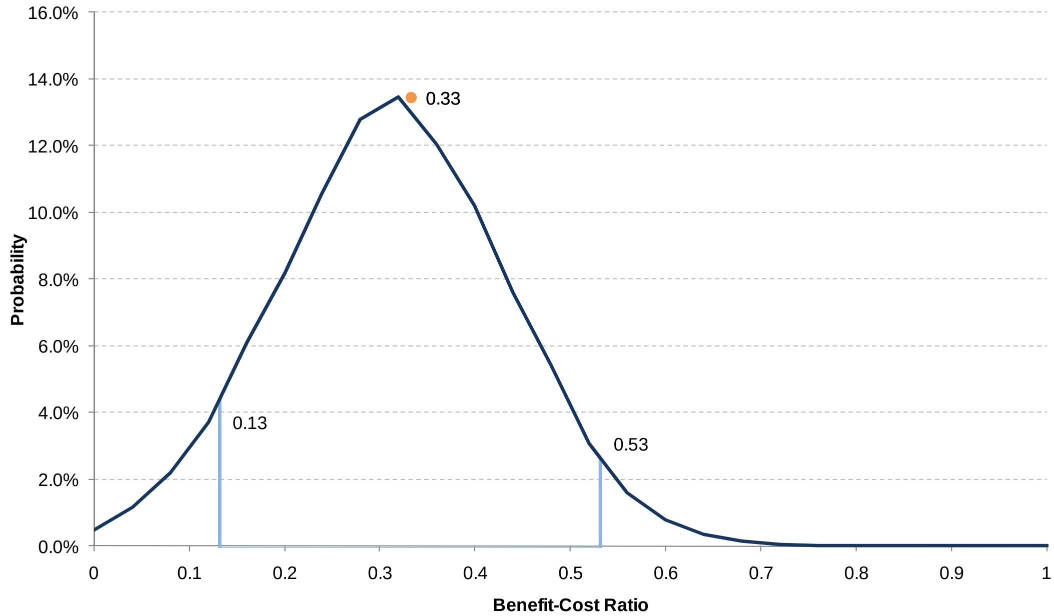
- Figure 6.12: Detailed breakdown of benefits (Houghton Highway duplication)



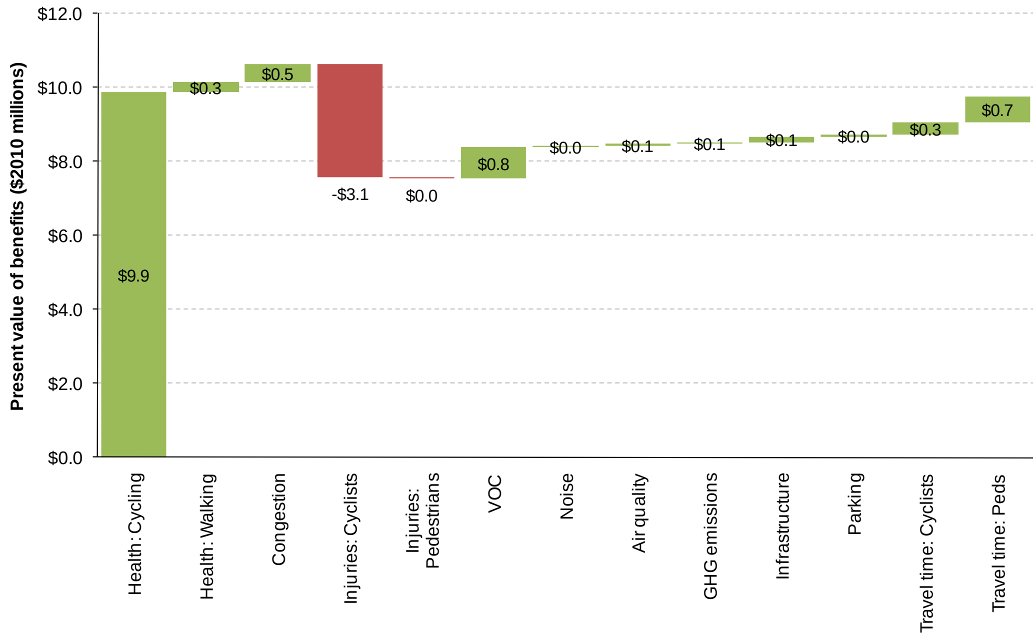
6.5 Gateway Upgrade Project

The shared path installed as part of the Gateway Upgrade Project is estimated to have a BCR of around 0.3, with a 95% likelihood that it falls between 0.1 and 0.5 (Figure 6.13). While the health benefits to cyclists dominate the benefit stream (Figure 6.14) it is notable there are benefits due to travel time savings for reassigned cyclist and pedestrian trips due to the assumed shorter travel distance thanks to the bridge. For the project to have a BCR of 1.0 the opening year cyclist demand would need to be around 550 cyclists/day (as opposed to the assumed 164/day).

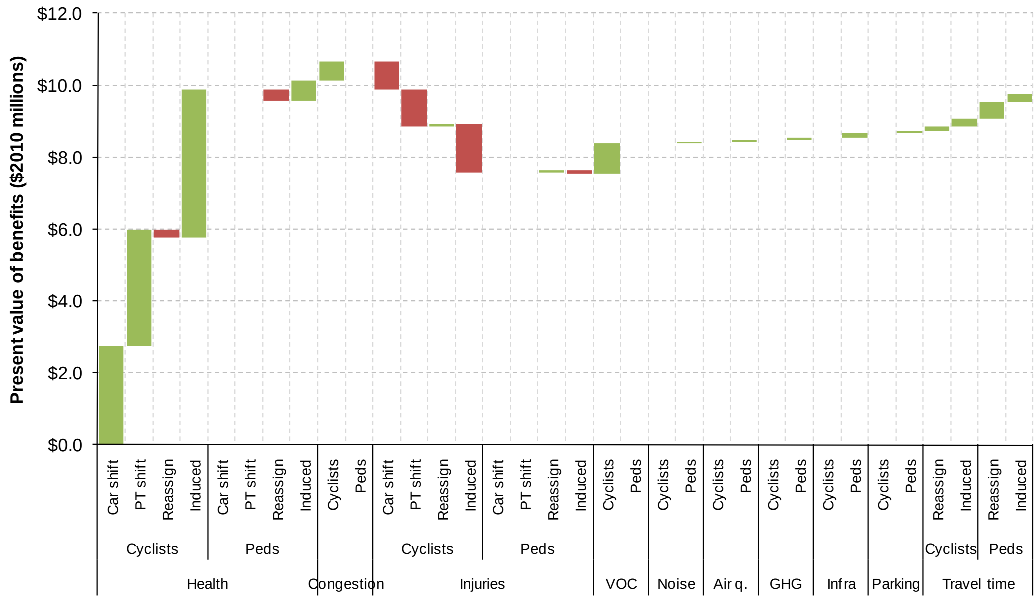
■ Figure 6.13: Benefit-cost ratio distribution (Gateway Upgrade Project)



- Figure 6.14: Summary breakdown of benefits (Gateway Upgrade Project)



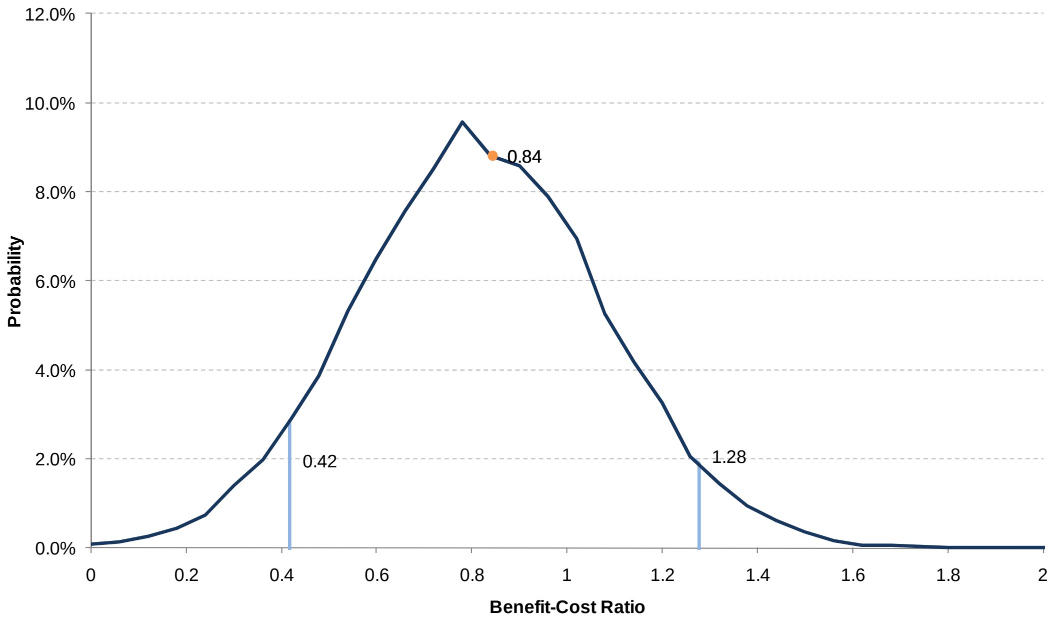
- Figure 6.15: Detailed breakdown of benefits (Gateway Upgrade Project)



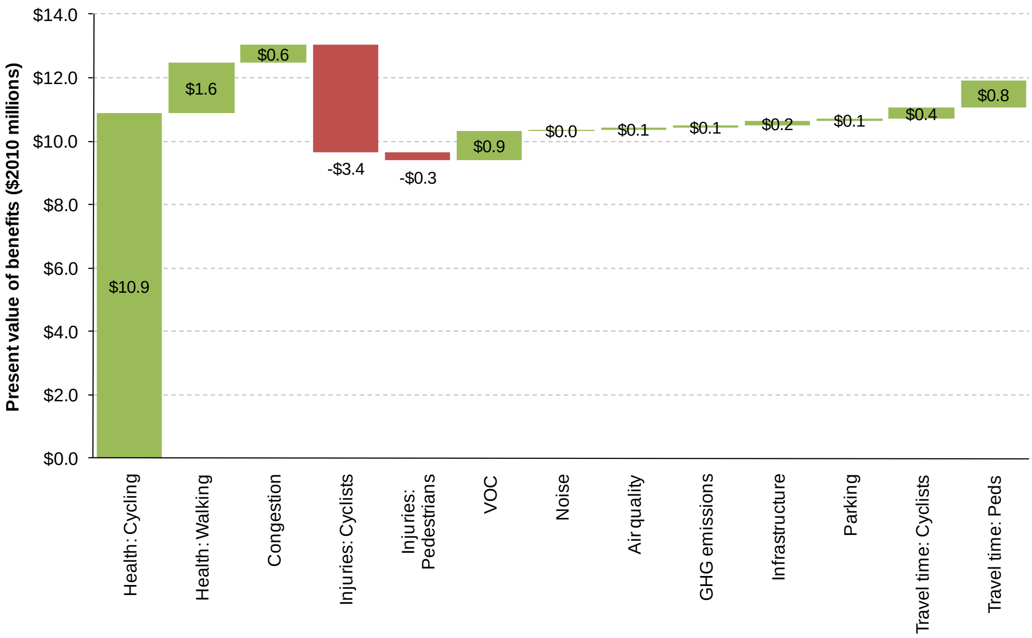
6.6 Normanby Cycleway and Pedestrian Link

The most likely BCR for the Normanby Cycleway would be around 0.8 (Figure 6.16). The opening year demand is assumed to be 440 cyclists/day and 228 pedestrians/day. For the project to breakeven the cyclist demand in the opening year would need to be around 550 per day (all else remaining equal).

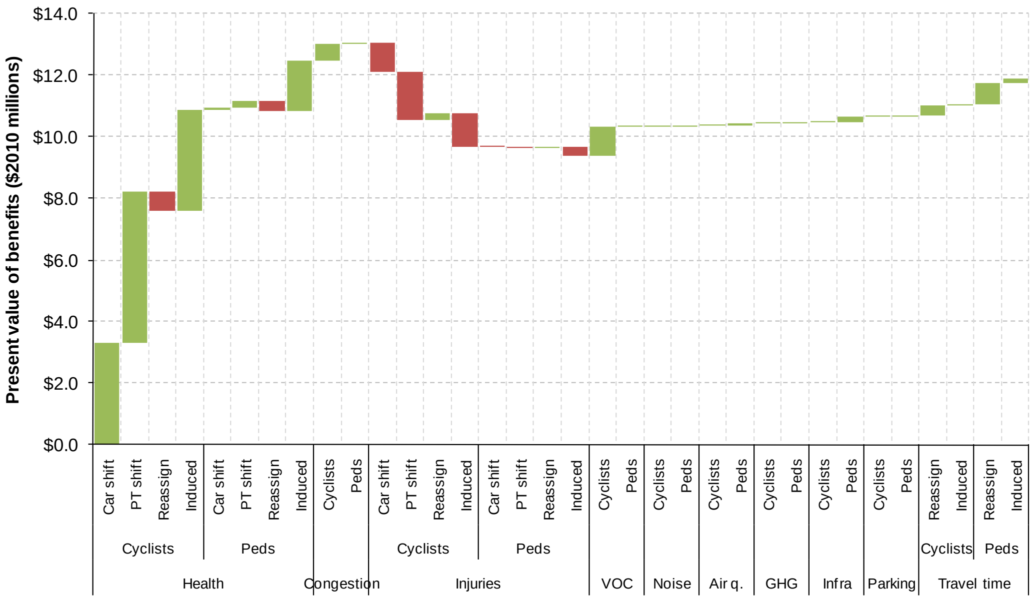
- Figure 6.16: Benefit-cost ratio distribution (Normanby Cycleway)



- Figure 6.17: Summary breakdown of benefits (Normanby Cycleway)



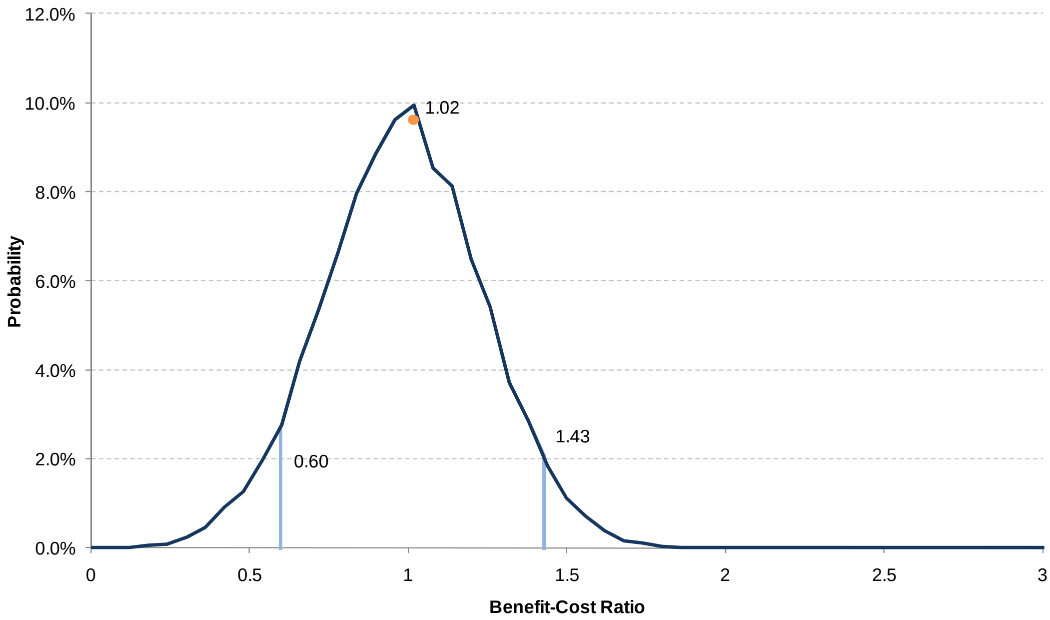
■ Figure 6.18: Detailed breakdown of benefits (Normanby Cycleway)



6.7 Go-Between Bridge

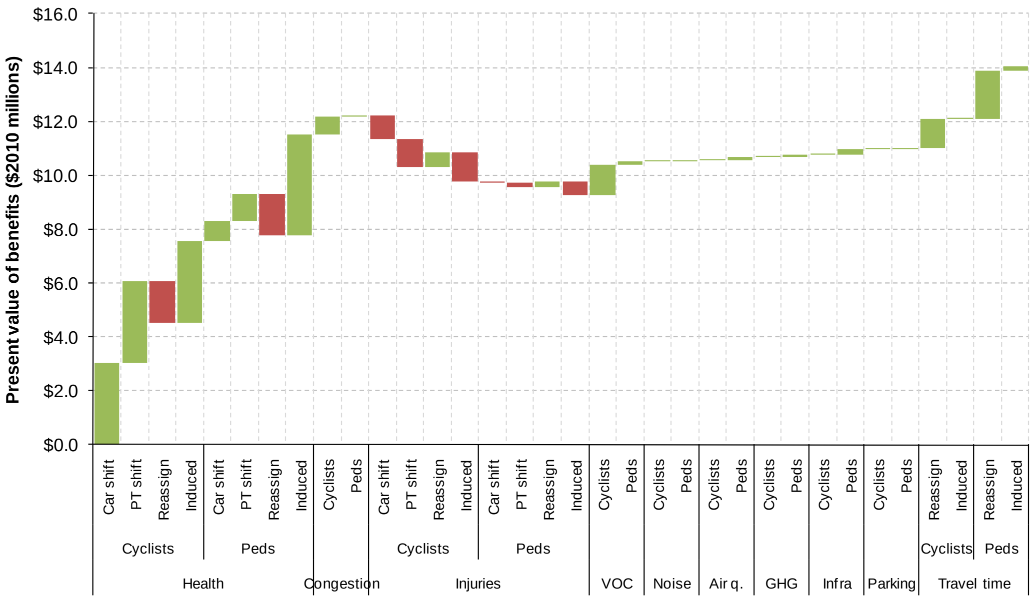
The Go-Between Bridge opened in July 2010, and provides a segregated cycleway (eastern side) and footpath (western side). It has been assumed in these calculations that the capital cost of the active transport component of the project was 5% of the total capital cost ($338m). The most likely BCR is 1.0, with a 95% likelihood that it will be between 0.6 and 1.4. The project benefits are primarily due to health benefits to pedestrians and cyclists, with some benefits coming from journey time savings for those existing cyclists and pedestrians who have changed their route to use the bridge (Figure 6.20 and Figure 6.21).

■ Figure 6.19: Benefit-cost ratio distribution (Go-Between Bridge)



■ Figure 6.20: Summary breakdown of benefits (Go-Between Bridge)

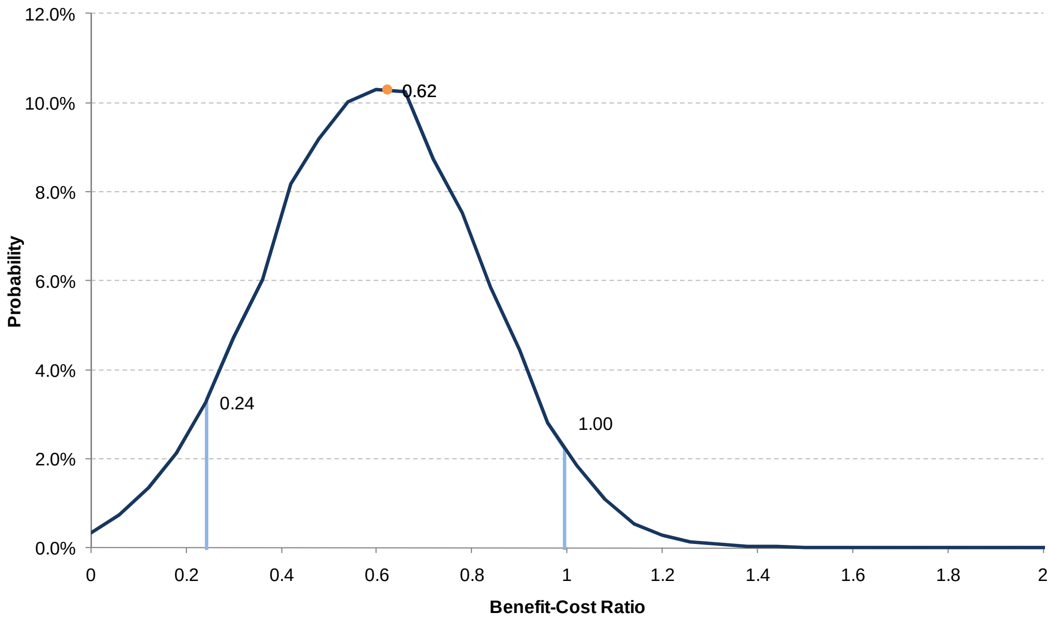
■ Figure 6.21: Detailed breakdown of benefits (Go-Between Bridge)



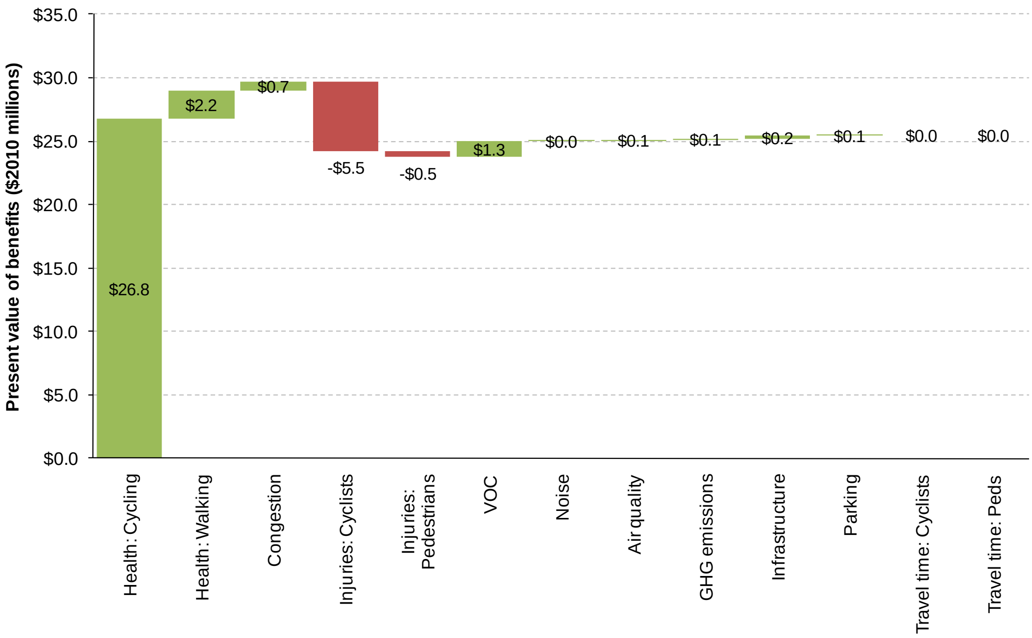
6.8 Moreton Bay Rail Link

The Moreton Bay Rail Link path is a proposed shared path running for 12.6 km alongside the proposed Moreton Bay Rail Link from Petrie to Kippa-Ring. For the purposes of this evaluation it is assumed the path would have demand identical to the Houghton Highway duplication (Ted Smout Bridge). Under these demand assumptions, and assuming a capital cost of $50m, the BCR for the project is most likely to be 0.6, with a 95% likelihood of falling between 0.2 and 1.0 (Figure 6.22). For the project to have a BCR of 1.0 the daily cyclist demand on opening would need to around 60% higher than forecast (1,600 trips/day compared with 970 trips/day).

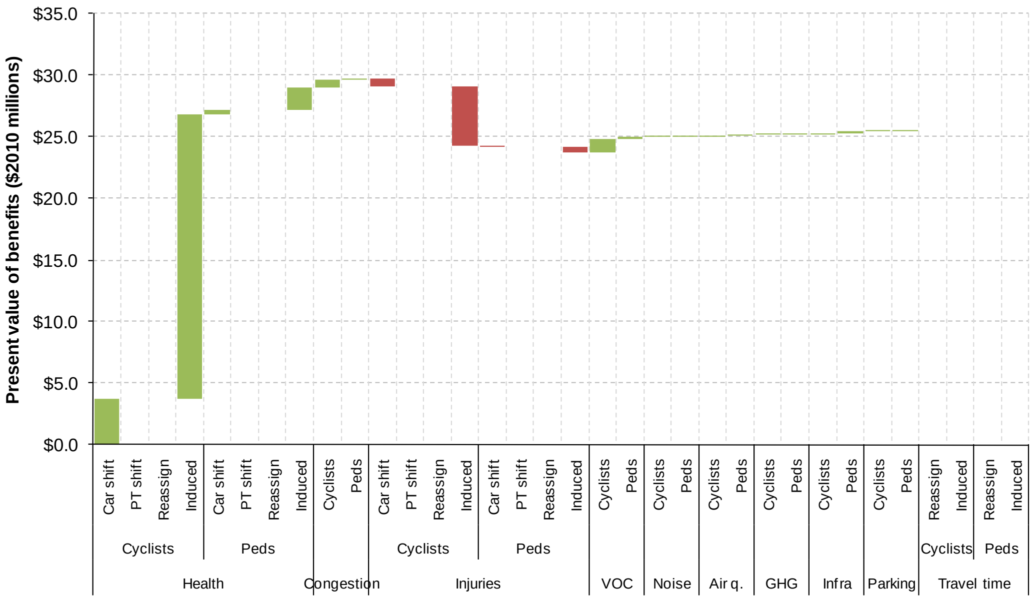
■ Figure 6.22: Benefit-cost ration distribution (Moreton Bay Rail Link)



■ Figure 6.23: Summary breakdown of benefits (Moreton Bay Rail Link)



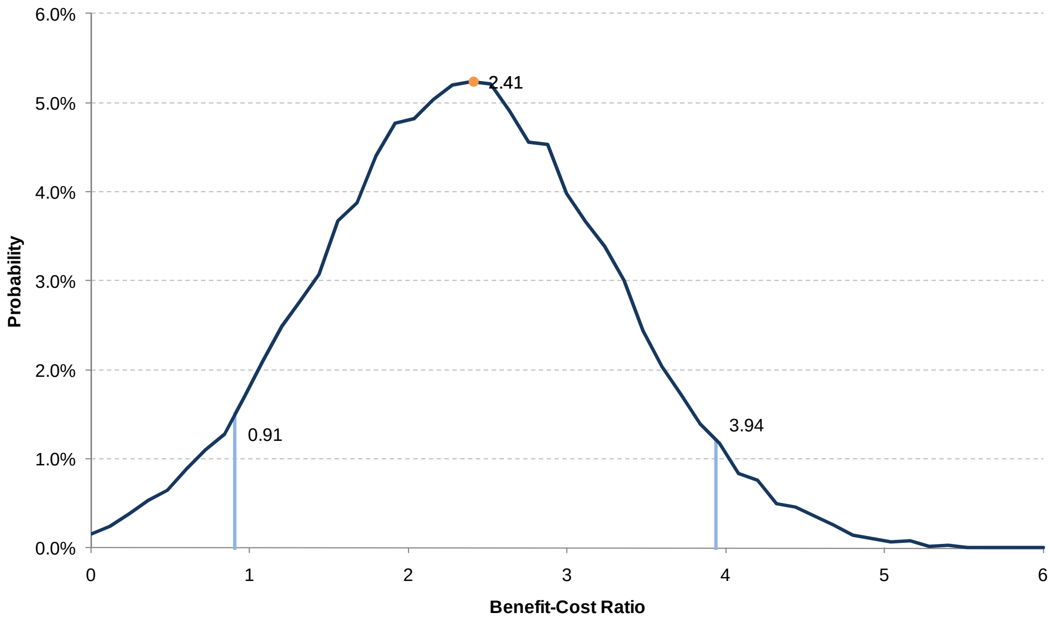
- Figure 6.24: Detailed breakdown of benefits (Moreton Bay Rail Link)



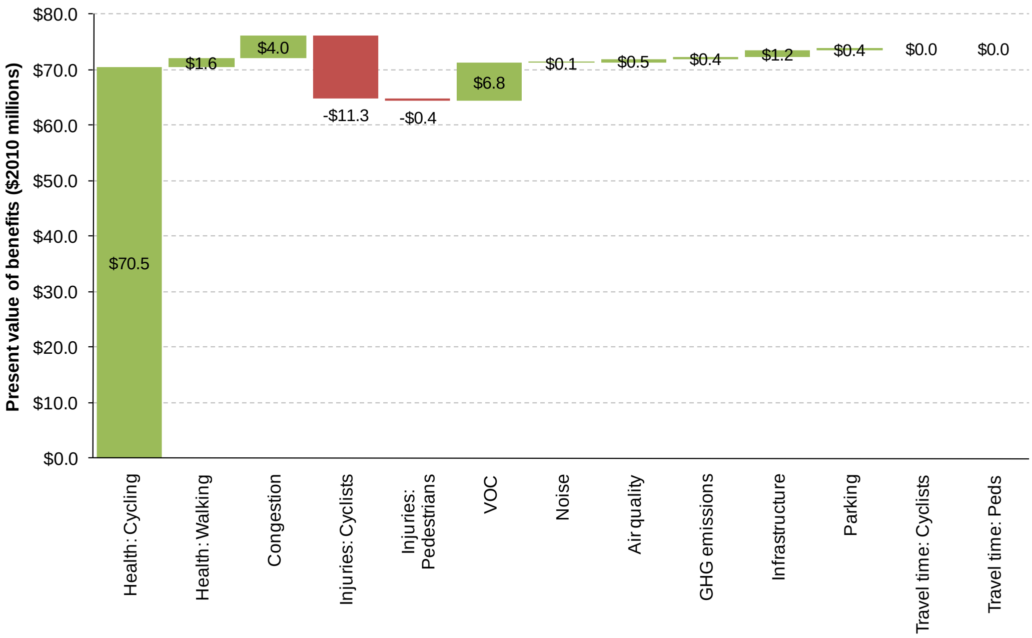
6.9 North Brisbane Cycleway

Indicative construction costs and demand forecasts (cycling only) for the North Brisbane Cycleway were developed by AECOM for TMR. In the absence of pedestrian forecasts it is assumed the pedestrian demand will be the same as on the Houghton Highway duplication. The BCR is most likely to be around 2.4, with a 95% likelihood of falling between 0.9 and 3.9 (Figure 6.25).

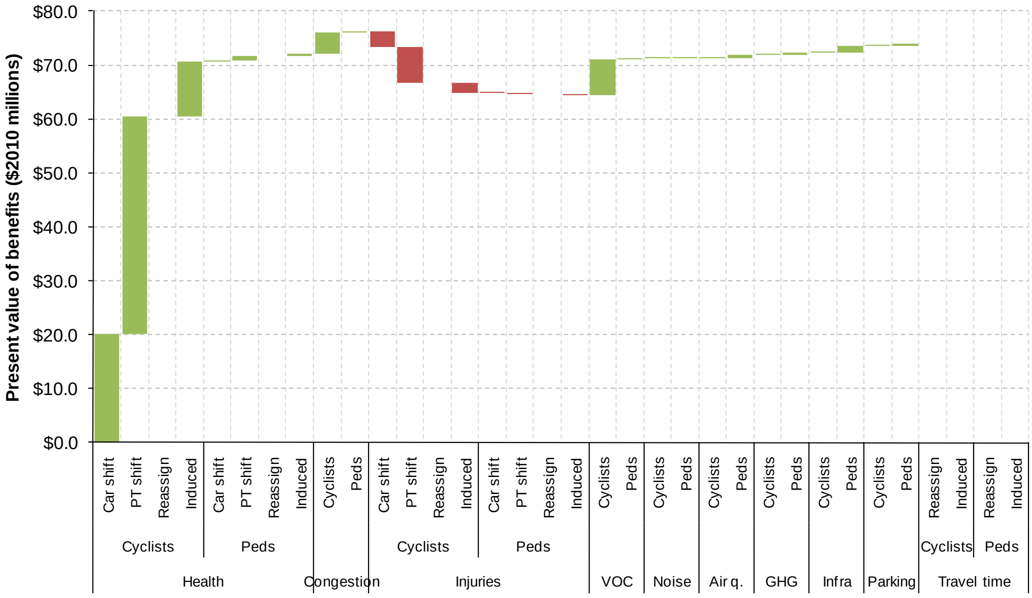
■ Figure 6.25: Benefit-cost ratio distribution (North Brisbane Cycleway)



■ Figure 6.26: Summary breakdown of benefits (North Brisbane Cycleway)



■ Figure 6.27: Detailed breakdown of benefits (North Brisbane Cycleway)



7 Other Issues

In this section we discuss a number of issues which have arisen in discussion with TMR and stakeholders. The purpose here is to set out some of the technical issues with these topics to assist practitioners in implementing the guidance discussed in this report.

7.1 Discounting

Discounting is an economics principle used to estimate the present value of future monetarised benefits or costs. In other words, it determines a ‘present value’ for future benefits or costs. The rationale for such an approach can be thought of in two ways:

- As an *opportunity cost*: if I can defer spending $100m for one year and instead earn interest at 6% then I will earn $6m next year in interest payments. Alternatively, if I were to spend this money now on infrastructure I would forgo this interest payment.
- As a *time preference for money*: there is strong research evidence to indicate that individuals prefer to receive benefits immediately; for example, a person would prefer to receive $1 today than wait for a year to receive $1. Similarly, they would prefer to defer spending $1 for a year than to spend it now.

This concept of discount rates is <u>not</u> related to inflation – it is calculated in real terms (that is, constant price terms).

The effects of discounting on a transport appraisal are profound; exactly when a cost or benefit is incurred will strongly influence the overall appraisal. At a typical discount rate of 7% then $100 of benefit in year 0 would be worth only $51 in present value terms if it were earned in year 10 or $26 in year 20.
This point can be further illustrated through three simple examples. Assume we have three choices:

1) Invest in a cycleway now, in 2012, that will cost $10m and have benefits of $500,000 in 2013 (when it opens), rising to $1m in 2014 and for every year thereafter (in 2012 prices).
2) Delay the investment until 2017 (a five year deferral), but assume the benefits and costs are identical to option 1.
3) Delay the investment until 2017 as for option 2, but this time assume the construction cost escalates to $150m (in 2012 prices) due to real growth in materials or labour costs (or perhaps because we miss out on the savings that accrue from building it alongside a larger construction project in 2012).

Option 1 and 2 would both produce a benefit-cost ratio (BCR) of 1.2, because the advantages of deferring the costs by five years are outweighed by the loss of the benefits over the near term (2012-2017). However, option 3 would only produce a BCR of 0.8 because of the 50% cost escalation and no commensurate increase in project benefits.

7.2 Combining active transport infrastructure with other projects

Where active transport infrastructure is provided with other major projects (for example, road or public transport infrastructure) the marginal costs of providing the active transport project are likely to be significantly less than if undertaken separately. Demonstrating the economic benefits of incorporating active transport into larger projects requires forecasting the marginal costs of construction both with the other project and independently. As the example in the previous section demonstrated, if demand after opening does not change with either option then the optimum outcome will be whichever produces the lowest costs. Experience and intuition would almost always suggest this optimum would be to incorporate the active transport project into the larger project.

If the marginal benefits of the active transport project outweigh the marginal costs (in net present values) then the active transport project on its own would be economically viable. More importantly however, if the larger project were to be appraised with the active transport component as an integral part of the project then the overall project BCR would <u>increase</u>. This may be important in situations where a projects economic benefits are marginal (that is, the BCR is close to one) as the addition of an active transport project may help make the overall project viable. There is at least one relatively large scale road safety treatment in Melbourne where this has been demonstrated to be the case – the project was economically unviable when evaluated purely on the road safety benefits to motorists, but became viable when the road safety benefits to cyclists and pedestrians were incorporated.

The NGTSM notes on the scoping of a project (Vol 3, Sect. 2.1.3 para 2):

> *Only combine initiatives when a single initiative, implemented by itself, produces little or no benefit until another initiative (or initiatives) is completed. In other words, there has to be significant synergies between the initiatives. To test this, there are said to be significant synergies if the NPV if the group of related initiatives, assessed together as though they were a single initiative, is significantly greater than the sum of the NPVs of the initiatives assessed individually.*

It may be argued for most active transport projects incorporated alongside other transport projects the synergies would be relatively minor (at current levels of active transport usage and in most, but not all, locations). The NPV test would more likely support the joint assessment of projects. This is because the significant additional capital cost of building the active transport project independently would result in a higher NPV for the group of projects rather than when treated individually. How significant this difference will be highly dependent on the relative magnitudes of the present costs and benefits of each project; it is possible that a rail or road project benefits and costs would have much higher magnitude than the active transport project. Nonetheless, there would be a case to demonstrate higher NPV (and BCR) from the combined project due to this capital cost saving.

7.3 Delay or avoidance of investment in other transport infrastructure

Under this scenario it is argued that an active transport project may defer or altogether eliminate the need for another transport project in the corridor. For example, an active transport project may defer the need for additional roadway capacity or public transport provision. To what extent this is possible will depend on the diversion rates from public transport to active transport along the corridor. In terms of economic appraisal the approach should be to appraise the options *together*. For example:

> If an active transport project were *not* built, it is determined through the demand model that an additional traffic lane on the adjoining freeway would be required in five years. An economic appraisal would assess the present benefits and costs of the necessary capital investment in the road project in five years.
>
> If alternatively an active transport were built adjacent to the freeway, and it were determined through demand modelling that this would defer the need for an additional traffic lane by two years then the appraisal would differ in the following respects:
>
> - the net present value of the capital cost of roadway construction would *reduce* thanks to an additional two years of discounting,
> - there would an additional capital cost due to the construction of the active transport project which would not be heavily discounted as these costs would occur up-front,
> - there would be an additional benefit stream that would accrue from the opening of the active transport project; these benefits would start accruing before the roadway widening and so would not be heavily discounted during early years.

In essence, the argument is that the standard economic appraisal framework (as incorporated within PAF) is an appropriate means to evaluate this type of scenario, under the condition that the wider scheme (incorporating both active transport and associated modes).

7.4 Travel time savings

In 'standard' transport appraisals travel time savings (a proxy used to measures changes in consumer surplus) will represent the majority of the scheme benefits (often half to two thirds of the total benefit). For active transport projects, travel time may not be a major determinant in mode choice; indeed, it is conceivable that in some cases the travel time by active transport may be longer than by motorised travel. For utilitarian travel the question then arises as to why a traveller would chose active transport if their travel time is extended; this would run contrary to economic theory which implies that all travellers are rational utility maximisers; that is, they look to maximise their benefits and minimise their perceived costs of travel. Travel time is typically valued negatively; that is, travellers look to minimise their perceived travel time. Economic theory would dictate that there must be other benefits beyond travel time which accrue to users in order for them to choose these modes and so conform to the rational utility maximisation concept. However, if the trip is made for its own purpose (i.e. going for a walk or ride with no specific destination) then the concept of travel time savings (and the willingness to pay for those savings) is mute.

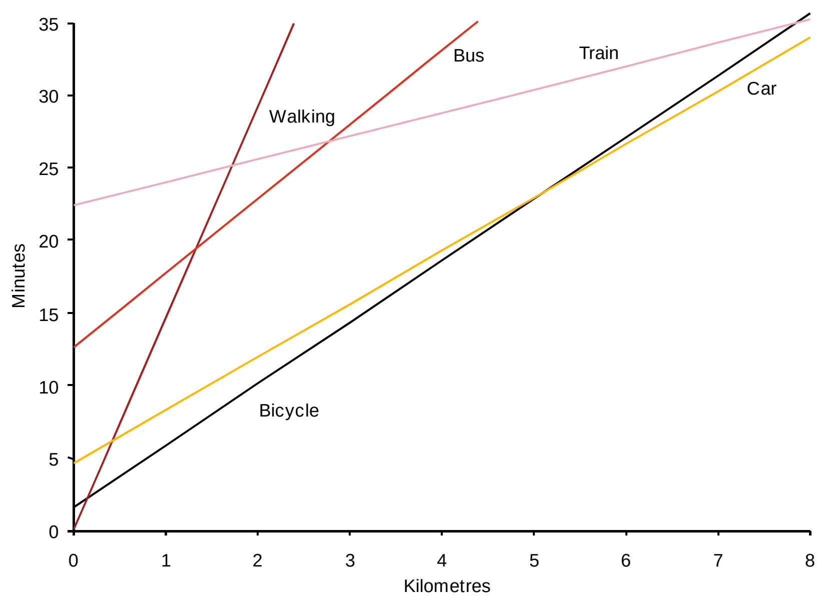
It is important to note that the perceived costs of travel extend beyond the time taken to undertake the journey. This perceived costs includes in vehicle time (IVT, or on-vehicle-time for cyclists), out-of-vehicle time (OVT), service quality attributes like comfort and security and perceived monetary costs like fares. This suite of perceived costs is often referred to the 'generalised cost of travel'. The value users place on various components of this generalised cost can be determined and then expressed as a weighting with respect IVT. For example, waiting for a train service (part of OVT) is often weighted at a value of two. This implies that the disutility associated with one minute waiting for a service is twice that of one minute travelling on board the service (IVT). Or put another way, a user deems one minute spent waiting for the train as equivalent to two minutes travelling on a train.

Understanding the perceived cost of travel is important in understanding what drives demand for active transport, especially when, as described above, actual travel time may be longer than on motorised modes. While travel time is one perceived cost in the generalised cost of active transport, additional perceived costs include the amenity of the ride, perceived health benefits and perceived safety characteristics. Each of these characteristics, and the impact they have on quantifying changes in travel time (consumer surplus) will be discussed in the following sections.

7.4.1 Changes in travel time

For short-distance travel, active transport may often be faster than motorised modes. Figure 4.1 shows the estimated average journey time against distance by mode in the urban environment. This indicates that the target market for diverting trips from private vehicles to walking is for distances less than 1 km and less than 5 km for cycling, when the time differential between car, walking and cycling, respectively are lowest.

■ Figure 7.1: Comparative journey speeds in the urban environment (BTRE, 2007)



The degree to which an active transport initiative will result in positive or negative changes in travel time will vary considerably depending upon the nature and goals of the project. If a specific project warrants the investigation of travel time savings then there are a number of further issues which need to be considered:

- when undertaken as a form of access to a public transport mode, active transport is given a weighting (as a component of out of vehicle time) to reflect the greater disutility compared to time spent in vehicle. This is common practice in all public transport and multimodal CBAs and is a fundamental requirement in the calibration of demand models.
- the purpose of the trip will determine the correct monetary value to apply in the quantification of travel time savings. Business and non-business purposes carry different values of time.

7.5 Journey ambience and perceived safety costs

Journey ambience for active transport usually refers to the type and location of the path, lane or dedicated infrastructure. The value active transport users place on journey ambience can be determined using willingness to pay surveys which explore the trade-offs people are willing to make to undertake a journey in a more pleasant environment. For example:

> *A 1 km route along a busy road without bicycle lanes is equivalent to a 2.5 km route on a busy road with bicycle lanes, 2.3 km route on a quiet street and 2.9 km route on an off-road path.*

Users are indifferent between these four scenarios, despite the different lengths (and hence travel times) of the routes, implying a willingness to incur almost three times the journey length to avoid the perceived safety costs of a busy road and the more amenable environment provided by the off road path.

The values users place on the amenity and safety of different active transport infrastructure is shown below in Table 4.1. These values (and hence travel times) reflect the reciprocal of the example above. For example, in Sydney the relativities between on-road (1.00) and an off-road path (0.34) imply a 1 km route along a busy road without bicycle lanes is equivalent 2.9 km on an off-road path (1.00/0.34 = 2.9).

- Table 7.1: Relative values for types of active transport infrastructure

Location	Harbourlink (PwC/SKM, 2010) Sydney	Wardman et al. (2007) UK	Tilahun et al. (2007) USA	Hunt and Abraham (2007) Canada
On-road	1.00	1.00	1.00	1.00
On-road with bike lanes	0.40	0.48	0.55	0.24
Off-road path	0.34	0.29	0.80*	0.36*

* Both authors argue that the higher weight for paths compared with on-road lanes is attributable to the need to interact with pedestrians and the typically lower speeds on off-road paths compared with roadways. In both studies only current regular cyclists were interviewed.

When undertaking a generalised cost of travel calculation for active transport the relative values attributable to different infrastructure types (which have inherently different perceived amenity benefits and safety costs) need to be applied as weights to travel times. This is the correct method for capturing changes in perceived amenity and safety in an active transport appraisal.

However, while the field of active transport demand modelling and economic appraisal have developed considerably over the past five years, undertaking this generalised cost calculation is complex and often beyond the remit of active transport appraisals. Calculating these generalised costs requires a calibrated demand model, founded upon local values. This model also needs to calculate the generalised costs of motorised and public transport travel, so that changes in travel behaviour (diverting between modes) can be captured once the option being tested is modelled. While this modelling is possible, the complexity (and costs) of such a task often exceed the nature and requirement of active transport appraisal.

As a result, other studies have attempted to quantify changes in amenity and safety costs in isolation from a generalised cost calculation which factors in all perceived costs. In terms of safety costs, this can be more easily achieved by examining the resource costs of accidents and how this may change under different active transport appraisals. If a willingness to pay value is used in these calculations then the perceived safety costs are better captured than if a human capital safety costs approach is used.

Capturing amenity outside of the generalised cost framework is more difficult. Some studies, such as AECOM (2010) used UK stated preference research to quantify these amenity benefits in isolation. While such amenity benefits are certainly valid in calculating a generalised costs, used to estimate demand for a new facility, they may introduce some degree of double counting in the economic appraisal if captured and quantified in isolation. For example, the health and safety (dis)benefits may already capture some of the perceived and real amenity benefits from an active transport project. Furthermore, some active transport projects will result in longer trip times for diverted users, which are outweighed by these positive amenity factors, resulting in a lower overall generalised cost in the option. Hence, it is important that amenity benefits be considered alongside travel time and other perceived benefits. If the amenity benefits were a minor contributor to the overall project benefits such issues may be of minor importance. However, as the appraisal by AECOM (2010) demonstrated, this benefit stream, when quantified in isolation, can contribute around a quarter of all project benefits[26]. As such, it is not a minor contributor to the benefit stream and so confidence in its applicability need be high.

7.5.1 Journey time reliability

One of the more significant benefits of active transport projects may also be improvements in perceived journey time *reliability*. That is, walking or cycling may offer a more reliable travel time than car or public transport. This is likely to be highly valued, particularly for commuting travel. However, while there has been extensive research undertaken in motorised transport to value reliability there remains much disagreement about exactly how

[26] In the particular project studied by AECOM it was however found that the BCR remained greater than one even with the amenity benefits excluded.

such reliability (or variability) should be measured, and how it should be valued[27]. Given this uncertainty, we do not feel there is sufficiently robust evidence to value reliability in active transport appraisal at this stage.

7.6 Perceived health costs

Perceived health benefits are likely to be a significant motivator for some to choose active transport. As a proportion of health care costs are perceived, and hence are a determinant for demand for cycling and walking, these costs should also be factored into the generalised cost equation. For example, a user may choose cycling over other modes of transport despite the longer travel times and poor amenity of having to share busy roads with traffic due to the perceived health benefits they receive from this trip. Hence, these health benefits are another reason, like amenity and safety that a user may choose to incur a longer travel times to undertake a cycling trip on poor road conditions.

Current active transport appraisals do not include perceived health benefits within generalised costs. This not only stems from the difficulties of specifying a generalised cost equation discussed above, but also the relatively young field of research for quantifying health benefits. Currently, this field has concentrated on quantifying the health benefits as an isolated benefit line item, however as appraisals and the level of research advances there is no reason why these perceived costs cannot be factored into an active transport generalised cost.

7.7 Real escalation of costs and benefits

It is acknowledged that the value of some input parameters will change in real terms over time[28]. Where this can be established, there is an argument that these real increases be captured within the appraisal framework. However, for the purposes of the current study, which seeks the practical application of technical parameter to help inform on policy decisions it is recommended that no real escalation should be included within the core results. Rather, the effects of real escalation should be captured within a sensitivity analysis, with the upper and lower bounds of this sensitivity range provided in the guidance above.

The primary reason behind this recommendation is to ensure consistency with other transport appraisals. It is not common practice for road, public transport or multimodal appraisals to incorporate these real increases within the quantification of costs and benefits. Hence, to ensure that active transport appraisals are treated on a comparable basis as other transport appraisals it is recommended that real costs are treated in the same manner. This is especially true when including real cost increases has the potential to significantly influence the present value outcomes of the appraisal.

[27] Much of the research available on multimodal travel time variability is from the UK; for example Batley *et al.* (2008).

[28] There will clearly be a change in these parameters in nominal terms (i.e. inclusive of inflation). However, it is the real values (i.e. exclusive of inflation) that are relevant to economic appraisal.

The arguments for including a real increase in a variety of costs and benefits have validity. However, it is important that all transport modes be appraised in a consistent manner. As such, any approach to applying real escalation in costs and benefits should be made consistently across all modes.

Specific real cost increases which warrant consideration (and are used to inform on the range of sensitivity tests) include:

- Vehicle operating costs and decongestion costs, which are likely to be influenced by a real increase in the price of fuel. However, it should be noted that this real increase will be offset, to a degree, by the increasing trend in fuel efficiency of motor vehicles.
- The cost of carbon is also likely to increase, although the extent of the increase is dependent upon legislation. Once such legislation is passed the trajectory, or market value of carbon, in future years can be determined and factored into the parameter value which quantifies the cost of carbon emissions to society on a per vehicle KM basis.
- Value of travel times are also likely to undergo real appreciation, with the wage price index within Australia consistently rising at levels exceeding economy wide CPI.
- Health care costs also display trends of real price escalation, which has the potential to influence the societal component of health benefits associated with active transport and a healthier population.

8 Further work

The appraisal of active transport projects remains underdeveloped in comparison to motorised transport. As such, there is a need for further work to refine the methods and valuations of benefits. Those avenues for further work which we view as most important are discussed in this section.

8.1 Demand

There is very limited data available on usage of existing active transport facilities, which in turn limits the ability to forecast demand for proposed facilities. Manual counts, while useful, are subject to significant seasonal and weather variation which can limit their usefulness in determining 'average' demand. Permanent counters, as are being used increasingly in Queensland which provides an accurate means[29] of counting cyclists. This data can be used to both understand the demand for particular facilities, but also to derive expansion factors and adjustment factors which can be used to adjust short period manual counts.

It is likely that project proponents would not, in most cases, be able to expend the efforts required to developed detailed demand forecasts. In many cases such detailed forecasts are unlikely to be warranted given the uncertainty in active transport demand forecasting methods. Instead, a compendium of data may be useful for proponents. Such a compendium may:

- Provide observed demand data of active transport projects in Queensland and Australia and their context so assist proponents in selecting appropriate demand assumptions
- Provide expansion and adjustment factors to enable proponents to adjust short period manual counts to estimate average demand suitable for the economic appraisal.
- Give an indication of trip lengths by mode by different types of facility.

8.2 Health benefits

The valuation of the health benefits is very important, as these benefits dominate the overall benefit stream and the unit values derived in this report are subject to considerable uncertainty. Specific areas requiring further research include:

- Studies of existing active transport projects to understand the physical activity prevalence of these users (ideally this would be done as a prospective study before and after a project were built).
- An understanding of the joint effects of multiple risk factors (including physical inactivity) on disease burden. In this study, the broad cause group DALYs attributable to physical inactivity were not adjusted for this effect, which will be overstating the impact of physical inactivity.

[29] Permanent counters on shared paths and cycleways can typically detect over 95% of cyclists and around 60% of pedestrians.

- Longitudinal studies with users of active transport projects who were sedentary or insufficiently active prior to the intervention to understand how much they use the facility, and what the health outcomes of doing so would be.

8.3 Injury risk

There is very limited data on the risk[30] of injury to cyclists and pedestrians on different types of active transport infrastructure (e.g. roads, on-road bicycle lanes, off-road paths and cycleways). Such risks are likely to be heavily dependent on detail design and context, such as intersection treatments and the speed and volume of motor vehicle traffic. Generalising such results by infrastructure type is likely to be difficult. However, as many active transport projects are justified, at least in part, on their safety benefits it is necessary to provide some indication of the safety benefits. Such a study is currently underway in NSW for cycling[31], which may provide further evidence which can be incorporated into this methodology.

Further investigation of the impact of safety in numbers effect is warranted, largely on routes in mixed traffic. Such a study would likely be longitudinal and require intercept surveys of cyclists to identify their crash history on the study corridor.

[30] The relevant unit here is risk (frequency per unit exposure) rather than injury frequency. The interest is in understanding how injury rates vary with changes in kilometres travelled. For example, if a project reduces cyclist kilometres travelled on road by 100 km but increases travel on a cycleway by 150 km what is the net change in cyclist injuries? A study currently underway in NSW for the RTA may ultimately shed some light on this issue.

[31] UNSW Safer Cycling Study: https://safercycling.unsw.edu.au.

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Appendix A: Intercept surveys

A.1 Introduction

In estimating the benefits of an active transport project it is necessary to estimate the *diversion rates* from other transport modes. The diversion rate is the number of passenger kilometres by non-active modes *reduced* as a result of mode shifting onto active transport. Understanding the reduction in passenger kilometres travelled by public transport and (particularly) private car is critical to the evaluation of the project benefits (e.g. fuel savings, decongestion and emissions reductions).

The diversion rate will vary depending on the type and quality of the infrastructure provided, how it fits within the broader active transport network and the attractiveness of the motorised alternatives. There is currently very little evidence available on diversion rates of active transport infrastructure either from Australia or overseas. Given this paucity of data, it was necessary to undertake primary research into diversion rates for existing active transport infrastructure in Queensland.

A.2 Background

The demand for a new active transport project will come from a combination of the following behavioural responses:

- **Reassignment:** Existing cyclists or pedestrians will change their route to use the new facility
- **Diversion:** users of other modes (car, public transport etc.) will change mode to ride or walk along the new facility
- **Destination switching:** users who previously travelled to or from other destinations by the current mode (cycling or walking) will change destination (and hence route) to use the new facility
- **Induced travel:** new trips will occur which previously did not occur at all.

Existing data on these rates in Queensland and other locations are provided in Table 2.1. Note that the metric used in this table is mode split; this may not necessarily concur with changes in passenger kilometres if there are (likely) route changes by mode shifting which result in changes in journey distances. However, evaluating the latter in practice is exceptionally difficult and so mode shift is considered an acceptable proxy.

While the methods used to determine these responses vary greatly, as do the context and types of infrastructure involved, it would appear that diversion rates can vary from around 20 to 80% of total demand, and much of this diversion comes from public transport (43 – 93%) rather than private car (6 - 30%).

One of the complexities of measuring mode shifts is that all journeys to some extent consist of more than one mode. For example, all car journeys will involve walk legs at either end of the trip and public transport trips may involve multiple modes (e.g. bus and train, or bus and ferry) as well as walking (or perhaps cycling). Diversion rates here are presented as a mode hierarchy (train, bus, ferry, car, bicycle, walk).

There are two ways in which the diversion rate may be estimated:

- It may be assumed that new active transport users will be attracted equally from all other modes, such that the diversions will be in proportion to the existing mode shares in the area or (better) along the corridor , or

- Intercept surveys of users on existing and (ideally) recently opened active transport infrastructure to identify what mode(s) were previously used.

Strategic transport modes such as the Brisbane Strategic Travel Model (BSTM) may provide mode shares along corridors of interest in Brisbane. However, there is limited evidence on current mode shares for trips for all purposes (not just commuting – for which the census provides good data) outside South East Queensland. Furthermore, there is no empirical basis on which to assume the diversion rates will be proportional to mode shares. It may, for example, be plausible that public transport users are more likely to divert to active transport than motorists (or vice versa). This indeed is what the values in Table 2.1 would suggest – that diversion from public transport is significantly greater than public transport mode shares would imply.

Given these uncertainties, and the usefulness in understanding the proportion of reassigned, destination switched and induced trips in addition to diversion, there are clear benefits in undertaking intercept surveys to build an evidence base. The methodology for these surveys is described in the next section.

- Table 0.1: Diversion rates (note: methodologies and survey design vary greatly between these studies)

			BEHAVIOURAL RESPONSE				DIVERSION FROM...				
Project	Mode	N	Reassignment	Dest. switch.	Induced travel	Diversion	Walk	Bicycle	PT	Car[1]	Reference
Goodwill Bridge	Bicycle	117	70%	—	—	30%	29%	n/a	51%	20%	Abrahams (2002)
" "	Walk	260	36%	—	—	64%	n/a	6%	65%	30%	" "
Eleanor Schonell Br.	Bicycle	109	38%	—	—	60%	2%	n/a	43%	17%	TMR (2008)
Public bicycle systems (Paris, Lyon and Barcelona)	Bicycle	n/a	n/a	n/a	n/a	n/a	27%	4%	54%	13%	Krykewycz *et al.* (2010)
Melbourne shared paths (1)	Bicycle	350	74%	5%	1%	21%	1%	n/a	60%	38%	Monash Univ. (2006)
Melbourne shared paths (2)	Bicycle		79%	—	1%	20%	0%	n/a	60%	40%	Rose (2007)
Ride to Work Day			36%	n/a	n/a	64%	6%	n/a	66%	28%	TMR (unpublished)
King George Square Cycle Centre	Bicycle	37	22%	—	—	78%	0%	n/a	93%	6%	Burke *et al.* (2010)

[1] 'Car' as used here refers to any private motorised transport such as cars, trucks, motorcycles or taxis whether as a driver or passenger.

A.3 Methodology

A brief intercept surveys of cyclists and pedestrians was undertaken at four sites in Brisbane (Sir Leo Hielscher Bridge, Go-Between Bridge, Normanby cycle and pedestrian link and Ted Smout Bridge). These sites were selected because they represented a reasonable variation of locations and were built relatively recently (all within the last four years).

The general outline of the survey was as follows:

- obtain high level information on route familiarity (how often they use this route will probably be a useful indicator of familiarity with alternatives)
- trip purpose
- approximate journey distance and travel time
- demographics
- mode used prior to the project opening (if applicable), and
- ask respondent what mode they would use if the route were closed for a short period of time[32].

The objective of the last of these questions is to obtain information on the diversion rate for those who either did not travel along this corridor prior to the infrastructure opening (perhaps because of churn) or could not recall which mode(s) they had used previously. We note that the short term response (e.g. over a few days) may differ from a longer term response (e.g. if the facility were closed for months or years). However, we do not want to give respondents the impression that there is any intention to close a facility – and so will only ask about the short term response.

A.4 Interview procedures

A minimum of two interviewers were located at each site for the interview period at a location which was conspicuous but did not impede movements through the area. The survey was designed for self completion; although in most cases where demand was relatively low the interviewer undertook the interview verbally.

[32] Our preference is to avoid a "what if this facility were not here..." type of question as this is more hypothetical than "if it were closed for a short period...", which is a conceivable scenario.

Minimising sampling bias is critical to obtaining a realistic picture of users of a facility. This means minimising the opportunity for respondents to refuse to participate and minimising selection bias[33] among interviewers. Best practice would dictate a random sampling strategy; for example, interview every fourth pedestrian passing the survey point. The downside to this strategy is that the total number of responses would be reduced (as interviewers would not be fully utilised). Given these issues, a convenience sampling approach – that is, to approach all users to complete the survey was used. Video was taken at each site and analysed afterwards to provide an indication of the proportion and mode of users who completed the interview.

A.5 Site selection

The selected sites were:

- Normanby cycle and pedestrian link (near Roma Street Parkland)
- Go-Between Bridge (South Brisbane, near Montague Street)
- Sir Leo Hielscher Bridge (Eagle Farm, near Curtin Street East)
- Ted Smout Bridge (Brighton)

The interview sites are shown in Figure A.1.

Each site had interviews conducted on a weekday and weekend. The times and dates over which interviews were conducted are given in Table A.1. Weather conditions varied from fine and sunny to cool and cloudy; no rain was experienced during interviewing.

■ Table A.1: Intercept survey dates

Site	Time	Date
Normanby cycle and pedestrian link	7 – 10 AM	Saturday 21 May
	7 – 9 AM	Monday 23 May
Sir Leo Hielscher Bridge	7 – 10 AM	Sunday 22 May
	7 – 9 AM	Tuesday 24 May
Go-Between Bridge	7 – 9 AM	Wednesday 25 May
	7 – 10 AM	Saturday 28 May
Ted Smout Bridge	7 – 9 AM	Thursday 26 May
	7 – 10 AM	Sunday 29 May

[33] Interviewer selection bias arises when interviewers approach only those users they perceive to be more likely to be receptive to an interview.

- Figure A.0.1: Intercept survey sites

(a) Sir Leo Hielscher Bridge

(b) Ted Smout Bridge

(c) Go-Between Bridge (cycleway)

(d) Go-Between Bridge (footpath)

(e) Normanby Cycle and Pedestrian Link

A.6 Results

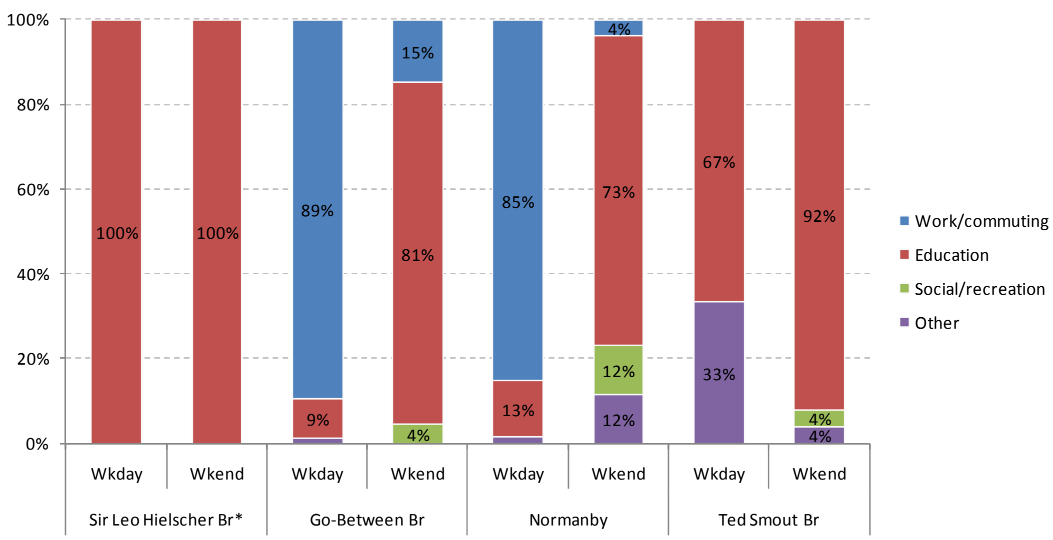
A total of 756 interviews were completed across all sites, of which 475 (63%) were cyclists. The breakdown of completions by site and day of week is given in Table A.2.

■ Table A.2: Interview totals

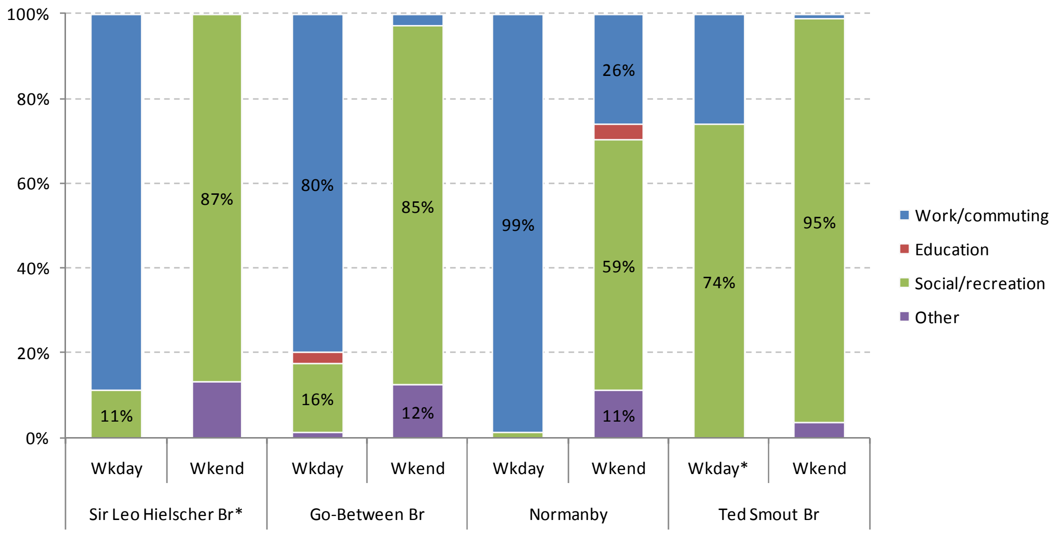
		Sir Leo Hielscher Bridge	Go-Between Bridge	Normanby Link	Ted Smout Bridge	TOTAL
Weekday	Cyclist	9	85	90	27	211
	Pedestrian	1	85	68	3	157
	Subtotal	*10*	*170*	*158*	*30*	*368*
Weekend	Cyclist	15	137	27	85	264
	Pedestrian	4	67	26	27	124
	Subtotal	*19*	*204*	*53*	*112*	*388*
TOTAL	Cyclist	24	222	211	112	569
	Pedestrian	5	152	94	30	281
	Total	*29*	*374*	*211*	*142*	*756*

The purpose split varied by location and day of week; the inner city sites had a predominantly commuter function on weekday mornings and recreational function on weekend mornings (Figure A.2 for pedestrians and Figure A.3 for cyclists).

■ Figure A.2: Purpose of trip (pedestrians)



- Figure A.3: Purpose of travel (cycling)



Most cyclists and pedestrians use the facility at least once a month, and most do so at least once a week (Table A.3). This suggests a good degree of familiarity with the corridor and alternatives to using the facility, which is important for understanding diversion.

■ Table A.3: How often do you use this path?

	Sir Leo Hielscher Bridge		Go-Between Bridge		Normanby Link		Ted Smout Bridge	
	Cyclist	**Ped**	**Cyclist**	**Ped**	**Cyclist**	**Ped**	**Cyclist**	**Ped**
7 days/week	2 (8.3%)	0 (0.0%)	33 (14.9%)	10 (6.6%)	24 (20.5%)	21 (22.6%)	7 (6.3%)	1 (3.3%)
Every weekday	1 (4.2%)	0 (0.0%)	24 (10.8%)	51 (33.6%)	41 (35.0%)	30 (32.3%)	6 (5.4%)	1 (3.3%)
1-4 times per week	10 (41.7%)	2 (40.0%)	147 (66.2%)	72 (47.4%)	48 (41.0%)	31 (33.3%)	70 (62.5%)	17 (56.7%)
Several times per month	5 (20.8%)	0 (0.0%)	7 (3.2%)	11 (7.2%)	1 (0.9%)	4 (4.3%)	15 (13.4%)	5 (16.7%)
Several times per year	1 (4.2%)	0 (0.0%)	0 (0.0%)	4 (2.6%)	1 (0.9%)	0 (0.0%)	5 (4.5%)	2 (6.7%)
First time today	5 (20.8%)	3 (60.0%)	11 (5.0%)	4 (2.6%)	2 (1.7%)	7 (7.5%)	9 (8.0%)	4 (13.3%)
Total	*24* *(100.0%)*	*5* *(100.0%)*	*222* *(100.0%)*	*152* *(100.0%)*	*117* *(100.0%)*	*93* *(100.0%)*	*112* *(100.0%)*	*30* *(100.0%)*

The proportion of respondents who had made this trip prior to the facility opening varied between sites (Table A.4); over 70% of respondents at Ted Smout Bridge indicated they had previously made this trip (as may be expected given the recent opening and presence of an active transport facility prior to opening). Unexpectedly, only 20% of pedestrians using Go-Between Bridge indicated they had made this journey previously (compared with 72% of cyclists).

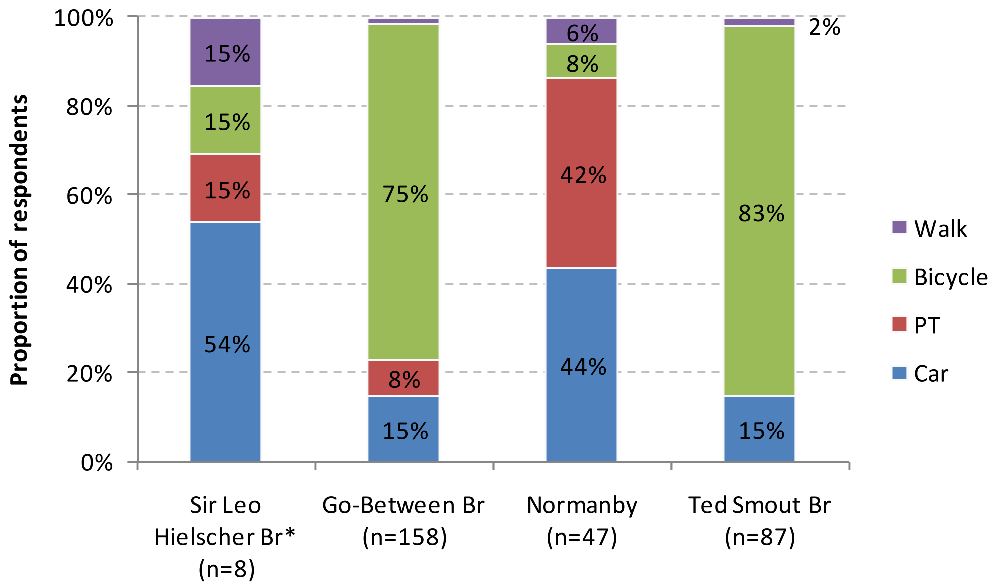
■ Table A.4: Proportion of respondents who had made their trip prior to the facility opening

	Sir Leo Hielscher Bridge	Go-Between Bridge	Normanby Link	Ted Smout Bridge	All
Cyclist	33.3%	72.1%	42.5%	78.6%	64.5%
Pedestrian	20.0%	20.5%	34.4%	70.0%	30.4%

Those who had made their trip prior to the facility opening were asked which modes they had previously used. As this question was multi-response, respondents could select multiple answers. For the estimation of diversion rates it is necessary to assume for those individuals who select multiple alternatives that they would do so in equal proportion. For example, if a respondent indicated they would previously have driven a car or taken a train it is assumed half the time they would have driven and the other half they would have taken the trail.

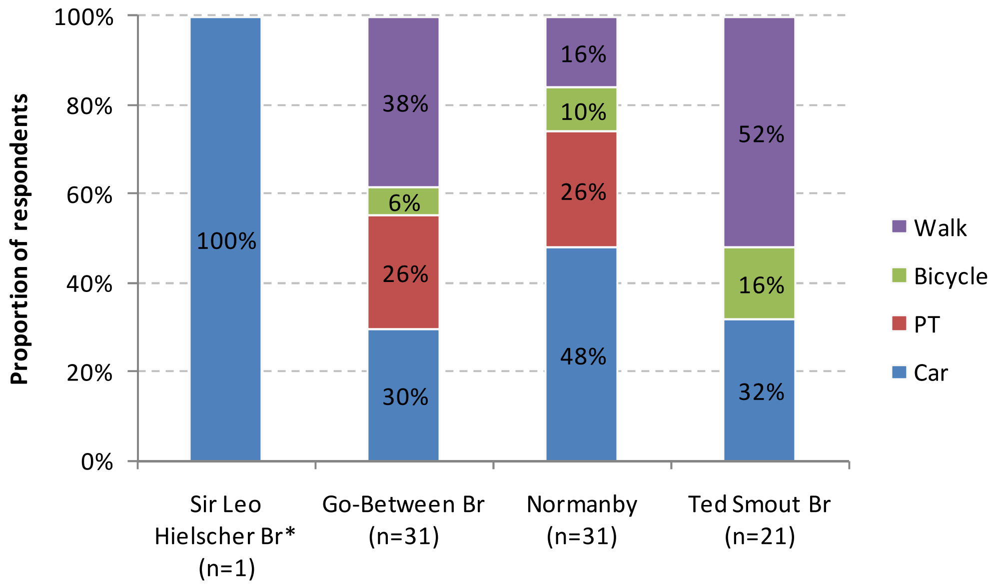
The proportion of cycling respondents who would previously have driven varies between 15% (Go-Between Bridge and Ted Smout Bridge) and 44% for Normanby cycle and pedestrian link (Figure A.4).

■ Figure A.4: Modes used by respondents prior to the facility opening (cyclists)



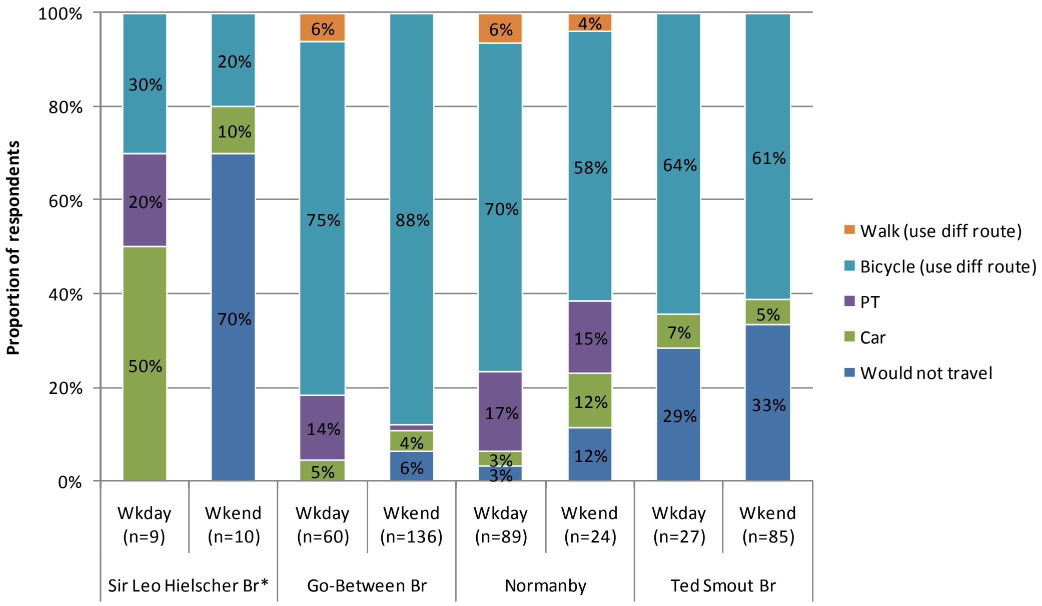
For pedestrians, around a third of respondents previously drove (Figure A.5). A further 38% of pedestrians on Go-Between Bridge previously used another route, as did 52% of pedestrians on Ted Smout Bridge.

■ Figure A.5: Modes used by respondents prior to the facility opening (pedestrians)



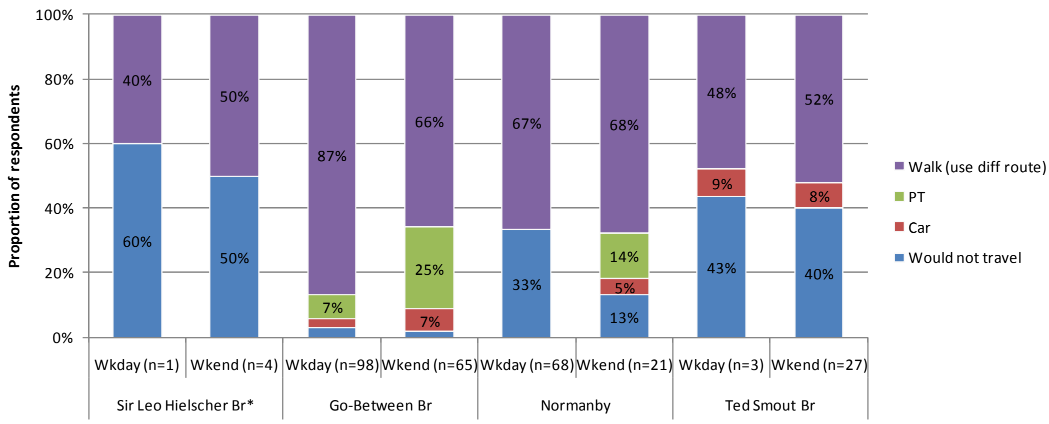
All respondents were asked what they would do if the facility were temporarily closed. Neglecting the Sir Leo Hielscher Bridge which had a very small sample size, at the other sites between 58% and 88% of cyclists would continue to ride but use a different route (Figure A.6). Less than 10% would not travel at Go-Between Bridge and Normanby cycleway, compared with around 30% at Ted Smout Bridge. This probably reflects the predominantly discretionary travel occurring at the latter. The proportion who would shift to car is 12% or less in all cases.

■ Figure A.6: Stated alternative to <u>cycling</u> on active transport facility



A somewhat different pattern is evident for those walking on the facilities (Figure A.7). Around 40% of pedestrians on Ted Smout Bridge indicated they would use an alternative route (presumably the old bridge, not yet dismantled at the time of the survey). At Go-Between Bridge, where there are multiple alternative bridge crossings in the vicinity, 87% of weekday pedestrians indicated they would have used an alternative route. Less than 10% of pedestrians at any site indicated they would have used car, and a small minority at Go-Between Bridge and Normanby would have taken public transport.

■ Figure A.7: Stated alternative to walking on active transport facility



A.7 Discussion

The diversion rates measured in the survey varied significantly depending on whether the question was phrased around what the respondent did prior to the facility opening compared with what they do now if it were (temporarily) closed. It is not altogether clear which result is more reliable; on one hand self-reported past behaviours are likely to be more reliable than stated preferences for some hypothetical future event (a temporary path closure). On the other hand, it may be difficult for respondents to recall what they did over a period of time that in some cases is 3+ years.

There are clear differences between sites which may reasonably be attributed to the purpose split (the inner city weekday interviews have very low levels of ‘would not travel’) and the location (Ted Smout Bridge has no individuals choosing public transport as an alternative). Given this variation, it will be appropriate to vary the diversion rates depending the site. The practitioner will need consider the most appropriate diversion rates given the local travel patterns and transport network. However, as a broad indication Table A.5 provides a rough breakdown based on the data obtained from this survey. It is emphasised that these diversion rates should be adjusted according to the local conditions.

■ Table A.5: Recommended diversion rates for active transport projects based on project location

	TO...			
	Cyclist		Pedestrian	
FROM...	**Inner City**	**Other Areas**	**Inner City**	**Other Areas**
Car	10%	15%	5%	10%
Public transport	20%	0%	15%	0%
Divert	65%	55%	70%	50%
Induced	5%	30%	10%	40%

Diversion rates for road and public transport projects are rarely reported. However, the ATC (2006) report diversion rates for three public transport projects which provide some sense check against the numbers reported above. As shown in Table A.6, the proportion of induced travel is around 30% and diverted users account for around 60% of travellers. These numbers are not dissimilar from those in Table A.5 for active transport projects.

■ Table A.6: Diversion rates for public transport projects (ATC, 2006)

Previous mode	Adelaide O-Bahn	Perth North Suburbs Rail	Bundoora (Mel.) tram extension
Car	19%	24%	16%
Divert from other PT	67%	65%	68%
Induced	9%	10%	11%
Other	4%	1%	5%
Total	*100%*	*100%*	*100%*

Another approach to dividing the diversion rates is by day of week (weekday, weekend). Such an approach is likely to be somewhat less reliable than an approach based on the project location (and, by implication, the availability of alternatives). Nonetheless, recommended diversion rates for cyclists and pedestrians based on day of week are presented in Table A.7.

■ Table A.7: Recommended diversion rates for active transport projects based on day of week

	TO...			
	Cyclist		Pedestrian	
FROM...	**Weekday**	**Weekend**	**Weekday**	**Weekend**
Car	10%	5%	5%	5%
Public transport	15%	5%	5%	0%
Divert	70%	70%	70%	60%
Induced	5%	20%	20%	35%