

Australian Transport Assessment and Planning Guidelines

M1 – Public Transport

May 2018



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ISBN: 978-1-925701-35-7 INFRA- 3584

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May 2018

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Mode Specific Guidance – Public Transport

At a glance

- This **Mode Specific Guidance – Public Transport** outlines methodologies for the economic appraisal of public transport initiatives, principally those in metropolitan (**urban**) areas. Its focus is on those aspects for which specific modal guidance on public transport is appropriate (supplementing the general methodology guidance provided elsewhere in the ATAP Guidelines).
- Following the introductory chapter, chapter 2 covers aspects of methodology for the estimation of travel demand (but excluding multi-modal modelling methodologies). Topics addressed include market research methods, demand estimation for initiatives using elasticity and diversion rate methods, and allowance for patronage ramp-up effects for new initiatives.
- Chapter 3 outlines aspects of cost-benefit analysis methodology and its application specific to the economic appraisal of public transport initiatives,
- Chapter 4 focuses on methods for estimating the economic benefits of public transport initiatives. Aspects covered include methods for estimating changes in consumer surplus, the implications of traveller misperceptions of the economic costs of travel, and other benefits of public transport initiatives (including environmental impacts, wider economic benefits, option values and non-use values, and transport disadvantage and equity aspects).
- Chapter 5 sets out default unit parameter values for application in assessing the economic benefits of initiatives to public transport users.
- Chapters 6 and 7 cover the suggested approach to estimation of capital and recurrent (operating) costs of public transport initiatives, and include guideline cost rates for public transport infrastructure, vehicles (rolling stock) and operational costs.
- Chapter 8 provides guidance on the measurement and monitoring of public transport system and service performance.

1. Introduction

1.1 Links to other parts of the Guidelines

This Mode Specific Guidance M1 complements the other parts of the ATAP Guidelines. M1 focuses specifically on public transport in an urban context. The material will assist practitioners to apply the generic material from other parts of the Guidelines, in particular T2 on cost–benefit analysis (CBA), to the economic appraisal of urban public transport initiatives.

M1 addresses aspects that are specific to public transport initiatives, where appropriate referencing concepts and data in other volumes of the Guidelines to minimise duplication. Some significant impacts of initiatives, such as social equity, cannot be readily expressed within an economic framework. Reference is made to the need to address such matters in the Appraisal Summary Table (AST), described in F3, 'Options generation and assessment'.

1.2 Public transport

Public transport initiatives do not have any unique features requiring them to be treated differently from other transport initiatives through the appraisal process. Even so, particular attention should be given to three matters throughout the appraisal process for such initiatives:

- With public transport initiatives, there is a particular need to take account of a broader range of associated matters compared with some other types of initiatives. These matters include network effects within a public transport system, inter-modal effects such as the transfer of travellers between car and public transport and other changes that affect road traffic, and the two-way relationship between public transport and land use.
- Ongoing costs associated with public transport are typically proportionately larger than for other types of transport initiatives and therefore need particularly careful consideration. These costs include operating and maintenance costs, re-investment in assets that reach the end of their lives during the initiative appraisal period, and additional capital for public transport fleet expansion needed to accommodate passenger growth during the appraisal period. Default data are provided in these Guidelines, but noting that costs vary between operators and situations, and analysts are encouraged to derive and apply data that is most appropriate to the initiative under consideration.
- Optimism bias, wherein costs tend to be under-estimated and demand over-estimated, is prevalent in major infrastructure projects, including public transport initiatives and road transport initiatives. Public transport analysts need to use best practice techniques to estimate costs and demand and should benchmark estimates against evidence from other comparable locations and situations. In undertaking such comparisons, it is important that analysts seek corroborating evidence, and also identify a range of other experiences and calibrate their own estimates against these experiences. For further discussion see Part O1 Optimism Bias.

Public transport initiatives will typically have a number of impacts that need to be taken into account in an economic appraisal. These impacts can be broadly categorised as:

- **Investment costs** – Investment costs incurred with the initiative (the Project Case), along with investment costs in the absence of the initiative (the Base Case), need to be taken into account. With public transport initiatives, substantial investment costs are commonly incurred in the Base Case and

also the Project Case, in part to re-invest in current fixed infrastructure and vehicle (rolling stock)¹ assets as these reach the end of their various asset lives.²

- **Operating and maintenance costs** – Over the life of most public transport initiatives, operating and maintenance costs will be substantial for the Base Case and Project Case, and more often than not will exceed the initiative's investment costs
- **Benefits** – The term 'benefits' includes all impacts on travellers and the wider community that result from the initiative, relative to the Base Case. Thus, if the impacts result in some people being adversely affected, benefits may be negative (disbenefits) as well as positive. Public transport initiatives can impact public transport users (e.g. through improved services), other road users (e.g. if some former car drivers shift to public transport) and the community at large (e.g. through changes in pollution and other social impacts). Particular care is needed to fully account for these benefits, but without double-counting.

The results of the economic appraisal are driven by the incremental changes that occur between the Base Case and the Project Case. This is the case for generating benefits, investment costs and operating and maintenance costs. In all cases, the Guidelines recommend that Base Case and Project Case numbers are explicitly reported to show how the incremental changes arise.

1.3 Relevance by scale of initiatives

The assessment of public transport initiatives will vary with the scale of the initiative. The smaller the initiative, the smaller is the need for the more detailed assessment techniques. Users should proceed as follows:

Major initiatives

For major initiatives, the guidelines presented here in Part M1 will apply in full. With respect to demand modelling, major initiatives lead to impacts across various modes. In urban public transport projects, multi-modal demand models are usually required — see Part T1 for guidance on their use. In cases where a multi-modal model is not available, or where the multi-modal effects are considered to be of a smaller localised scale, the simpler techniques presented in Sections 2.2 and 2.3 of this document can be used.

Smaller initiatives

Smaller initiatives will have lower costs, and lower risks. Simpler assessment techniques will usually suffice — although rigour in their application is still important. The demand effects will also be primarily restricted to public transport, meaning that a multi-modal demand model won't be required.

In assessing smaller initiatives, the following points will assist the user in simplifying their task:

- Chapter 2: The methods in Section 2.2 are suited to application to smaller initiatives (compared with the multi-modal methods in T1), especially Section 2.2.3. Where mode shift is considered to be small, Section 2.2.4 will be sufficient.
- Chapter 4: Assessments that assume there are no modal shifts will simply result in benefits to existing public transport users. This simplifies the assessment of benefits, not requiring use of the 'rule-of-a-half' or the logsum methods. There is also no increase in fare revenue (Section 4.4). Nor are Sections 4.7, 4.8

¹ The term 'vehicles' is used in the Guidelines to cover all vehicles and rolling stock used to carry passengers e.g. buses, trams/LRV, trains and ferries.

² With respect additional investments over the appraisal period that may be needed to meet population growth or other drivers of service growth, there are two approaches in Australia. Infrastructure Australia (2017) require that such additional investments not be accounted for in the Base Case or Project Case unless funded or committed by Government. The other approach, to include them in both cases, is used by some jurisdictions. See further discussion of Base Case definition in ATAP Part T2 Section 1.6.

or 4.10 required. In Table 14, benefits will be restricted to items 1a, 3a (e.g. safety and environmental impacts of more public transport services) and 3c.

- Chapter 7: Cost estimation will usually only require deterministic methods rather than probabilistic. The Australian Government only requires probabilistic estimation if the cost of the initiative is greater than \$25 million.

The above suggestions for smaller initiatives also applies for rapid appraisal.

1.4 Structure of this guidance

The remaining chapters in this volume address the following aspects of the economic appraisal of urban public transport initiatives:

- Chapter 2: Travel demand estimation, including principles for assessing travel demand, elasticity and diversion rate methods for public transport demand estimation, market research methods for application in public transport demand forecasting, patronage ramp-up, annualisation factors for public transport demand and user benefits, and risk and uncertainty in public transport demand estimation.
- Chapter 3: CBA methodology, including specification of the base case and the project case, identifying options, the appraisal period, change in benefits over time and the benefit-cost ratio.
- Chapter 4: Methodology related to the estimation of the benefits of initiatives, including the misperception of travel costs and its implications, methods for estimating changes in consumer surplus, other benefits of public transport initiatives (such as environmental externalities, wider economic benefits, option values and non-use values, and transport disadvantage and equity), and the calculation of the economic benefits of an initiative.
- Chapter 5: Default unit parameter values for application in assessing the economic benefits of initiatives to public transport users. With respect to values of time, the chapter presents behavioural values of time for use in travel demand modelling and refers to equity values of time for use in economic appraisal.
- Chapter 6: Public transport resource estimation methods, vehicle capital costs and capacities, default operating costs, and associated risks and uncertainty.
- Chapter 7: Fixed infrastructure capital costs, including a general approach to infrastructure cost assessment, consideration of risk and uncertainty, and provision of default indicative unit capital costs.
- Chapter 8: Approach to the measurement and monitoring of public transport system performance.

2. Travel demand estimation

This chapter is concerned with principles and methods for estimating future demand for public transport travel, particularly methods for forecasting how future demand would be affected by potential service, quality and price initiatives.

The chapter should be read in conjunction with T1, which covers travel demand modelling and forecasting methods for transport generally. The multi-modal metropolitan/regional ('four stage') models discussed in T1 are used to assess major transport initiatives, and would also generally be used for appraising major public transport infrastructure initiatives. This current chapter complements T1 by discussing the simpler demand forecasting methods specific to public transport and which are generally used for smaller and less complex initiatives, and which usually apply elasticity-based or related methods.

The chapter is structured as follows:

- Section 2.1 sets out principles for assessing public transport travel demand.
- Section 2.2 outlines public transport demand estimation methods (excluding multi-modal modelling methods covered in T1) in some detail, focusing on elasticity-based and related diversion rate methods.
- Section 2.3 provides evidence on the patronage 'ramp-up' profiles over the initial years following the introduction of an initiative, prior to demand reaching its 'equilibrium' state (which is the usual focus of forecasts).
- Section 2.4 outlines methods and factors for translating demand forecasts (from models or other sources) for specific periods into annualised demand and user benefit estimates, for economic appraisal purposes.
- Section 2.5 discusses risk factors and uncertainties arising in public transport demand forecasting and how these are best addressed.
- Appendix A summarises market research data sources and analysis methods, for application in deriving parameters for elasticity-based and related demand forecasting methods.

2.1 Principles for assessing public transport travel demand

The following principles should be adopted when assessing public transport travel demand:

- Any initiative that improves public transport could be expected to increase public transport use. However, the extent of the effect on demand can vary (as follows).
- Some public transport initiatives may have no (or minimal) effect on the use of other modes (e.g. car, walking or cycling). In this case, any additional use of public transport will be demand generated by the improvement).
- It is possible for some public transport initiatives to attract travellers from other modes without affecting overall travel demand. However, this is generally unlikely because most significant improvements in public transport can be expected to generate some additional public transport travel as well as attract some users from other modes. In addition, a transfer of some motorists to public transport may in some instances reduce traffic congestion, which could be expected to affect road travel demand.
- A public transport initiative that has a significant effect therefore has potential to result in generated and diverted public transport travel and second-order effects on road use.

The estimation of the impacts of a public transport initiative on the quantity, location and mode of travel is generally undertaken through:

- Use of an integrated computerised multi-modal travel demand model (sometimes referred to as 'four-stage' models) – see T1, or

- Use of a computerised public transport demand model (using 'elasticised matrix' or similar methods to estimate demand changes), or
- A spreadsheet or paper-based approach that considers changes in travel on a simpler basis, such as using elasticities of demand with respect to travel variables.

The second and third methods are discussed in Section 2.2 below. Note that T1 Section 3.3 provides a related discussion on demand elasticities.

The appraisal methodology is similar, in principle, for all these approaches. However, the accuracy and level of detail that can be represented in the appraisals will differ. Differences in the form and detail of the data available from them may also require some differences in how analysts apply the data for appraisals.

Limited detailed data are available to show the effects of public transport improvements in Australian cities on travel demand. In particular, there is limited data to show the extent to which users of a new or improved facility were existing public transport users or former car passengers or drivers, or if the initiative created new trips. The limited available data on 'diversion rates' are presented in Section 2.2.4.

2.2 Elasticity and diversion rate demand estimation methods

2.2.1 Overview

As noted in Section 2.1, a range of methods are used for estimating the impacts of smaller and less complex public transport initiatives on the demand for travel (e.g. by mode, location, time of day). Several of these methods use travel demand elasticity estimates in some form, as described further in this section.

Three methods are outlined here:

- *Generalised cost elasticity matrix method* – Computerised public transport demand models may use an 'elasticity matrix' approach by which the public transport demand for each origin–destination movement varies in proportion to the change in the generalised cost of travel for the origin–destination pair. In this case, generalised cost elasticity values define the relationships between the % change in generalised costs and the % change in demand for each origin-destination pair.
- Section 2.2.2 provides typical generalised cost, or generalised time, elasticities consistent with the typical public transport generalised cost formulation.
- *Elasticity components method* – Simple models for assessing changes in fares, travel times or frequencies on existing routes may use specific (component) elasticities relating to fares and travel times to estimate changes in public transport demand.
- Section 2.2.3 provides component elasticities relating to specific journey attributes, for use with simpler models or methods where public transport modes or route structures are not changed.
- *Cross-modal methods* – Models which estimate the effects of public transport initiatives on demand for other modes, by applying cross-elasticity or 'diversion rate' evidence.
- Section 2.2.4 provides 'diversion rates' or cross-elasticities relating to the previous modes of the additional public transport passengers attracted by service quantity, service quality or fare changes.

2.2.2 Generalised cost elasticity of demand³

The weight of Australian and international evidence indicates typical elasticities of urban public transport demand with respect to total generalised costs (or generalised time) as:

- Short-run (within 12 months of change) – peak -1.0; off-peak -1.5 to -2.0
- Long-run (7–10 years after change) – generally indicated in the economic literature as being approximately twice the short-run values; however, the Australian evidence on ramp-up profiles (Section 2.3) indicates that this factor applies only to major infrastructure schemes, while the speed of ramp-up is much greater for smaller public transport schemes and hence the long-run: short run ratio much lower. Further discussion on the trends of elasticities over time is given in Section 2.3.

Apart from the differences between peak and off-peak values, the weight of evidence suggests generalised cost elasticities are reasonably stable over a wide range of urban public transport situations across developed countries. However, it should be noted that:

- Weekend elasticities are generally higher than weekday (off-peak) elasticities
- Elasticities tend to be higher than average for short trips, where walking is a competitive alternative, and lower than average for medium and long-distance trips
- There is no evidence of systematic differences in generalised cost elasticities between different urban public transport modes, apart from the distance effect.

2.2.3 Component direct elasticities of demand

Table 1 presents a set of **short-run** default elasticity estimates for public transport demand with respect to fares, service levels and in-vehicle time.

Table 1 Short-run component elasticity estimates

Attribute	Best estimate (default) values			Typical ranges
	Overall	Peak	Off-peak	(All periods)
Fares	-0.35	-0.25	-0.50	-0.2 to -0.6
Service levels ⁽¹⁾	+0.40	+0.30	+0.50	+0.2 to +0.7
In-vehicle time	-0.40	-0.30	-0.50	-0.1 to -0.7

Note: (1) Best estimates reflect medium frequency (20-30 minutes headway). As noted in the text, service level elasticities may be higher than indicated in this range in evenings and weekends when frequencies are relatively low.

The following points should be noted in relation to Table 1:

- These elasticities may be used for all urban public transport modes — there is insufficient evidence of any intrinsic differences in elasticities between modes, other than those relating to trip lengths, service frequencies etc. (see discussion in Table 2).
- The elasticity values are disaggregated by peak and off-peak periods for two reasons: because of the significantly different aggregate demand between these time periods; and as a proxy for strong differences between market segments (particularly work and commuting trips versus shopping,

³ This section addresses the impacts of changes in public transport travel (generalised) costs on car travel demand, but does not attempt to address the impacts of changes in car travel costs such as changes in fuel prices or parking charges on public transport demand. These impacts may be addressed through strategic transport models or by using cross-elasticity or similar methods.

recreational and social trip purposes. Most evidence indicates that off-peak elasticities are around twice peak elasticities, essentially reflecting the market segment differences in the different time periods.

- In addition, elasticity values also tend to vary with the contribution of the component to the total journey generalised cost, broadly consistent with the assumption of constant generalised cost elasticity within the table. Thus, service level (frequency) elasticities increase, more or less, proportionately with service headways, up to at least an hourly frequency. One outcome of these two effects together is that, for example, service frequency elasticities in off-peak periods with low service levels are substantially higher than in off-peak periods with relatively high service levels, which are in turn higher than in peak periods.⁴
- Fare elasticities should be applied to fare changes in real terms—that is, after adjustment for any inflationary effects.
- Table 1 does not include any elasticity values for service reliability. However, in the case of unreliable services, the elasticity with respect to the standard deviation of service arrival times may be around -0.7 to -0.8, approximately twice the elasticity for in-vehicle time.
- Table 1 relates to short-run component elasticities (i.e. after 12 months from implementation of the initiative). For the long-run, the best evidence is that in the case of major infrastructure-based initiatives elasticities are about twice the short-run values for all three variables; but for smaller public transport schemes, long-run elasticities are typically around 5 % to 20% greater than the 12-month values. See Section 2.3 for a related discussion on demand ramp-up.

Table 2 provides further evidence of how the Table 1 component short-run elasticity estimates vary across a range of market situations and trip characteristics. The following points should be noted in relation to the evidence in Table 2:

- Strong systematic variations in elasticities exist between trip purposes and time periods (the two factors being strongly correlated) for all three variables. Weekday off-peak elasticities are around twice peak period elasticities and weekend elasticities are generally higher than weekday off-peak values.
- Elasticities vary in a complex way with trip distance: this can be explained in part by the availability of substitutes, with high elasticities for short trips having the alternative of walking; and in part by the importance of the component measure in the total trip generalised cost.
- Elasticities vary with city size, although the fare effect and the service level effect appear to be opposite. However, there is limited data relating to this issue.
- Both fare elasticity and service elasticity significantly vary, although rather less than proportionately with the magnitude of the base fare or headway. This is particularly significant in regard to service headways: a typical service elasticity would be around 0.2 at short headways (better than every 10 minutes) increasing to around 0.5 to 0.6 or more at longer headways (hourly or longer). These variations are broadly consistent with a constant generalised cost elasticity formulation.
- Most studies show no significant difference in elasticities between fare increases or decreases, or large or small fare changes. Similarly, the limited evidence on service elasticities suggests no significant differences in elasticities between service increases and decreases, or between large and small changes.

Table 2 Summary of evidence on component elasticities for key variables

Aspect	Elasticity variable		
	Fares	Service levels	In-vehicle time
Trip purpose/ time period	Off-peak/non-work typically twice peak/ work; weekend most elastic	Off-peak/non-work typically about twice peak/work; weekend most elastic (may be	Inconclusive regarding relative elasticities, although most

⁴ Analyses by Wallis (RR 487, 2013) found that bus service frequency elasticities in several Australian cities on weekend evenings were around 1.0, some 3-4 times the elasticities for weekday peak periods.

Aspect	Elasticity variable		
	Fares	Service levels	In-vehicle time
		partly due to frequency differences)	evidence is that off-peak is more elastic than peak
Mode	Bus elasticities typically somewhat greater than rail (but largely reflects shorter bus trip lengths)	No evidence of significant differences (apart from variations with headway)	Bus elasticities typically lower than rail (reflecting longer trips by rail with in-vehicle time a greater proportion of generalised costs)
Trip distance	Highest at very short distances (walk alternative), lowest at short/medium distances, some increase and then decrease for longest distances (beyond urban area)	Highest at short distances (walk alternative)	Limited evidence – longest trips more elastic than short/medium distance trips
City size	Lower in larger cities (over 1 million population) – US evidence	Higher in larger cities – EU evidence	No evidence
Base level of variable	Elasticities increase with base fare level, but less than proportionately	Elasticities increase with headways, but less than proportionately	No firm evidence, although expect elasticities to increase with proportion of total trip (generalised costs) spent in-vehicle
Magnitude of change	No significant variation in elasticities with magnitude of change (most studies)	No significant variation in elasticities with magnitude of change (most studies)	No evidence
Direction of change	No significant differences for fare increases and decreased (most studies)	Evidence does not indicate significant differences between service level increases and decreases	No evidence

2.2.4 Modal switching impacts of public transport improvements

When public transport services are improved, the additional patronage observed on the public transport system originates from a variety of prior modes and other sources, principally:

- Previous car use (as driver or passenger) for the trip in question
- Previous active mode use (as pedestrian or cyclist) for the trip in question
- Generated trips (i.e. the same or a similar trip would not have been made at all without the public transport improvements).

Two alternative approaches are often used to estimate cross-modal effects involving the application of (i) cross-elasticity relationships; or (ii) diversion rates (the preferred method).

Cross-elasticity approach

This approach derives cross-modal elasticity estimates from experience elsewhere in broadly comparable situations, and then applies these to the level of change (%) in the public transport service features (e.g. fare levels) to estimate the extent of change (%) in the use of the previous mode. For example:

- Assume public transport service levels are increased by 30%
- The cross-elasticity of car driver demand with respect to public transport service levels is estimated, from experience elsewhere, at -0.10

- Hence the service level increase will change car (driver) use in the area/corridor in question by $30\% \times -0.10 = -3\%$, (i.e. a 3% reduction).

A significant volume of international literature exists on cross-elasticities of demand for alternative modes with respect to public transport fares, service and other changes, although this literature is less extensive than on the corresponding direct elasticities (e.g. refer Balcombe et al. 2004, Wallis 2004).

While the evidence is that direct elasticities (for a given market segment) are generally quite consistent across different countries and cities, this is not the case for cross-elasticities: cross-elasticities are found to be proportional to the previous mode share ratio (i.e. public transport mode share/alternative mode share), and are therefore not readily transferable unless these initial mode shares are taken into account when considering the cross-elasticity evidence⁵. Given this, the remainder of this section focuses on the 'diversion rate' approach as the preferred method.

'Diversion rate' approach

The 'diversion rate' resulting from a public transport initiative is the proportion of the 'new' public transport passengers who previously made the trip in question by the specified mode (e.g. as car drivers). In this context, the 'new' public transport passengers are those who did not previously use public transport for their trip.

Table 3 provides evidence from a range of Australian and international sources of the patronage impacts of major urban public transport initiatives in terms of the previous travel modes of their users. For each initiative, it shows the proportionate breakdown according to previous mode of travel for:

- Total patronage following the initiative – unbracketed figures, and
- 'New' public transport passengers only (i.e. those who did not previously use public transport for the trip). These proportions (shown in brackets in the table) represent the diversion rates from each previous mode.

These results show a good degree of consistency across the range of schemes of different types and in different countries. One finding is that, on average, some two-thirds of all users of major public transport initiatives had previously used public transport for their trip. Of the remaining (approximately one-third) users of the new initiative, typically 40% 50% would otherwise have made their trip by car, with the majority of these (circa 35% to 40% of new public transport users) making the trip as car drivers.

This finding applies to the various schemes (involving major infrastructure investments) included in the table. In addition, it should be noted that:

- For public transport initiatives particularly oriented to attracting motorists, use of the higher car driver diversion rates is appropriate. These include initiatives such as park & ride facilities and express bus services, each with diversion rates from car drivers of over 50% and in some cases as high as 70% to 80%.
- For public transport initiatives with a more 'social' focus, use of the lower car driver diversion rates is appropriate. These include off-peak fare schemes and suburban bus route enhancements. For these schemes, the diversion rates from car driver may be as low as 20% to 30%.

The mapping of Table 3 with the terms diverted and generated trips is as follows:

- The 'did not travel' column represents newly generated trips

⁵ The relationship between the cross-elasticity of demand for mode i with respect to changes in mode j (e_{ij}) and the own (direct) elasticity of demand for mode j (e_{jj}) is as follows:

$$e_{ij} = e_{jj} \cdot (Q_j/Q_i) \cdot \partial_{ji}$$

where (Q_j/Q_i) represents the relative market shares of the two modes and ∂_{ji} is the relative measure of the demand change in mode i compared with the demand change in mode j (which is commonly referred to as the diversion factor or diversion rate).

- The 'existing PT users' columns represents trips diverted from one public transport mode to another
- The other columns represent trips diverted to public transport from other modes.

Table 3 Previous mode of travel by public transport users (and diversion rates) after the implementation of major public transport projects % ⁽¹⁾

Initiative	Proportions of market by previous modes						Existing PT users	Overall total
	Car driver	Car passenger	Did not travel	Walk/ Cycle	Other	Total		
Australian/NZ schemes								
Adelaide O-Bahn	13 (41)	6 (18)	9 (27)	* *	4 (14)	33 (100)	67	100
Melbourne SmartBus	21 (31)		25 (37)	4 (6)	19 (28)	68 (100)	32	100
Auckland Northern Busway (Express service)	32 (72)	11 (24)	* *	1 (2)	1 (2)	44 (100)	56	100
Perth Northern Suburbs Railway	23 (66)	1 (3)	10 (29)	* (*)	1 (3)	35 (100)	65	100
Bundoora (Melb) Tram extension	* *	16 (49)	* *	11 (36)	5 (15)	32 (100)	68	100
UK Heavy/Light Rail Schemes								
Birmingham (cross-City rail link)	11 (30)		26 (70)		* *	37 (100)	63	100
Merseyside Rail (link/loop project)	20 (45)		24 (55)		* *	44 (100)	56	100
West Yorkshire (new rail stations)	16 (52)		13 (42)		2 (6)	31 (100)	69	100
Manchester MetroLink	14 (48)		15 (52)		* *	29 (100)	71	100
Glasgow Rail (cross-city rail link)	15 (50)		15 (50)		* *	30 (100)	70	100
London Underground	20 (51)		19 (49)		* *	39 (100)	61	100
UK Busway Scheme								
Cambridgeshire Guided Busway	20 (57)	11 (30)	* *	3 (8)	2 (5)	35 (100)	65	100
European Light Rail Scheme								
Grenoble LRT	5 (42)		4 (33)		3 (25)	12 (100)	88	100

Nantes LRT	10 (30)	16 (48)	7 (21)	33 (100)	67	100
Nieuwegein LRT	8 (35)	10 (43)	5 (21)	23 (100)	77	100

Note: (1) Figures not in brackets show the proportions of passengers using the new service broken down by their previous mode of travel. Figures in brackets show the proportions of new public transport passengers (resulting from the initiative) broken down by their previous mode of travel (i.e. the relevant diversion rate).

(2) * means not covered in this survey

2.3 Patronage ramp-up

Travel demand forecasts are normally based on equilibrium states—the demand after taking full account of all impacts of the initiative. However, in the real world these full impacts rarely occur instantaneously. Typically, there is an initial ('short run') impact which subsequently continues to increase over time ('long run') although at a gradually decreasing rate. Even within the first 12-month period (often taken as the 'short-run'), there is an initial rapid response (within the first few days and weeks) which thereafter continues to grow, but at a decreasing rate. While the economic literature tends to focus on the changes in demand over the period from 12 months to 5 to 10 years following implementation of an initiative, the changes within the first 12-month period are also important for public transport initiatives, particularly for budgeting purposes.

The term 'ramp-up' is often applied for public transport (and also road) initiatives, to the pattern of demand growth over time from the introduction of an initiative until the demand reaches its 'equilibrium' state (typically after 5 years or more). It should be noted that this 'ramp-up' effect refers only to the underlying growth in demand towards equilibrium: any other changes that may occur over the ramp-up period (e.g. as a result of changes in demographic or economic factors, or in the transport system) need to be addressed separately and, as appropriate, added to the ramp-up effect.

'Ramp-up' information relating to public transport initiatives, and particularly different types of initiatives, has tended to be an under-researched topic internationally, including in Australia. However, two recent research projects in Australia help to fill some of the previous research gaps on this topic:

- Research in SE Queensland⁶ analysed information on ramp-up profiles for different types of public transport initiatives for up to 5 years following their introduction, with the initiatives being categorised as follows:
 - Service frequency changes on existing routes (principally bus mode) – increases and reductions
 - Route and connectivity changes (all modes, including multi-modal) – including new routes, route variations, new and upgraded stops and stations, park & ride facilities
 - Major corridor initiatives (all modes) – including large-scale bus and/or rail corridor improvements, typically with substantial infrastructure components
- Research on the demand effects of increasing bus service levels (generally through frequency enhancements) in Melbourne, Brisbane and Adelaide⁷ provided considerable information on 'ramp-up' profiles for initiatives in this category for up to 5 years following their introduction.

⁶ MRCagney Pty Ltd (2012). TransLink service and infrastructure evaluation framework (STEP). Part 1 – ramp-up profiles. Report to TransLink Transit Authority.

⁷ Wallis IP (2013) Experience with the development of off-peak bus services. NZ Transport Agency research report 487. 384pp.

Both these research projects found that patronage ‘ramp-up’ profiles followed a saturation curve pattern, with the ‘sharpness’ of the curve (i.e. its initial steepness and its subsequent transition to a reduced growth rate) being dependent on the type of initiative. The saturation curve that best fitted the data in most cases was of the following hyperbolic form:

$$P_t = P_s * t/(B + t)$$

where: t = time since introduction of the initiative

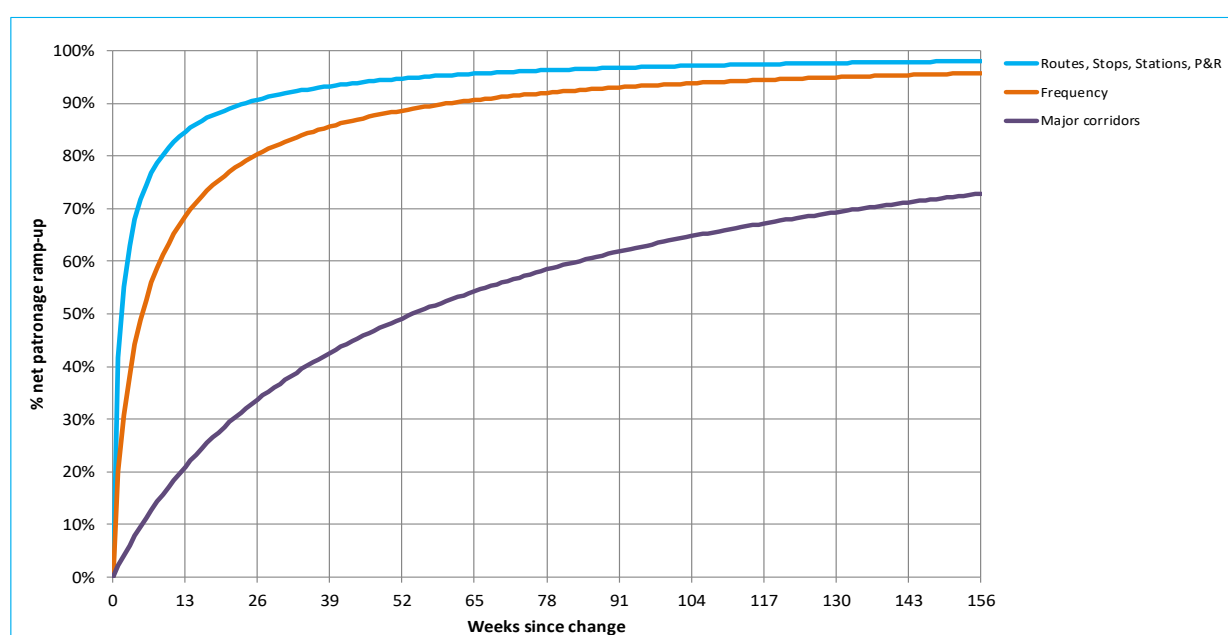
P_s = estimated patronage impact or growth at equilibrium situation (‘saturation’)

P_t = patronage impact at time t

B = constant (reflecting the ‘sharpness’ of the saturation curve, dependent on the type of initiative). It can readily be shown that B represents the time at which patronage growth reaches 50% of its saturation level (when $P_t/P_s = 0.5$, $t = B$).

Figure 1: Typical public transport patronage ramp-up profiles from service changes shows typical ramp up profiles (from the SE Queensland research) for each of the three categories of initiatives identified above. Table 4 sets out, for each of these typical profiles, the proportion of the equilibrium (saturation) patronage growth that occurred by the end of each quarter and year, over the first 3 years from introduction of the initiative. It also shows the ‘B’ value (the time at which the patronage growth reaches 50% of its saturation level) for each profile illustrated; and related directly to the ‘B’ value, it gives the ratio of the patronage growth estimated at saturation relative to the growth after 12 months. Note that for major corridors they would typically not reach saturation for many years.

Figure 1: Typical public transport patronage ramp-up profiles from service changes



Source: MRCagney 2012

Table 4 Patronage ramp-up profile data by category of initiative

Category of initiative	'B' value (weeks)	% of equilibrium value at end of period						Ratio of saturation to 1 yr value
		Q1	Q2	Q3	1 Year	2 Year	3 Year	
1. Route and connectivity changes – including new, extended and realigned routes, new/upgraded	2.2	85%	91%	93%	95%	97%	99%	1.04

Category of initiative	'B' value (weeks)	% of equilibrium value at end of period						Ratio of saturation to 1 yr value
		Q1	Q2	Q3	1 Year	2 Year	3 Year	
bus/train/ferry stops, stations and park'n'ride								
2. Frequency changes – including frequency increases and reductions	6.1	69%	80%	86%	89%	94%	96%	1.12
3. Major corridors – including large-scale bus and rail improvements in urban areas.	54.9	21%	34%	43%	49%	65%	73%	2.06

Source: MRCagney 2012

The following comments on the interpretation of these ramp-up profiles should be noted:

- The profiles given in Figure 1: Typical public transport patronage ramp-up profiles from service changes and Table 4 represent the averages of a number of profiles derived from the SE Queensland data for the individual initiatives within each category.
- In this regard, the profiles for categories for which multiple initiatives have been implemented and monitored (e.g. service frequency changes) may be regarded as more reliable than those for categories for which few initiatives were available for analysis (e.g. major corridor projects). Reference may be made to the original study report (MRCagney 2012) for more details.
- These profiles have been based on **net** changes in system patronage resulting from each initiative: these net changes are after allowing for patronage changes on competing or complementary services as well as on the route directly affected by the initiative—as distinct from the gross changes, measured on the directly affected route only.
- The 'sharpness' of the 'ramp-up' curve (as measured through its 'B' value) seems to largely reflect the type and extent of the service changes in each category:
 - The 'sharpest' response was for the 'connectivity' category (1), which in most cases involves minimal changes in the services themselves, but primarily in the stop/station arrangements (including park & ride provision)
 - The next 'sharpest' is the service frequency change category (2), for which passengers would also be expected to become familiar and take advantage of within a relatively short period
 - The least 'sharp' (slowest ramp-up) is category (3), major corridor projects, which tend to induce considerably greater changes in travel behaviour, and which travellers take longer to explore and take advantage of.
- Apart from category (3), the other two categories have relatively 'sharp' ramp-up profiles, with patronage growth within 1 year accounting for at least 90% or thereabouts of the expected saturation growth. For category (3), the corresponding figure after 1 year is around 50% of the expected saturation level.
- The ratios of saturation ('long-run') patronage growth to growth up to month 12 are 1.04 for category (1), 1.12 for category (2) and 2.06 for category (3).
- It is notable that the 2.06 growth ratio for category (3) is very similar to the ratio of long-run to short-run service elasticities of 2.0 commonly quoted in the public transport economic literature (refer Section 2.2.2). While the ramp-up evidence here indicates that this ratio may be a good approximation for major public transport improvement schemes, it is clearly not valid for the majority of smaller improvement schemes found in practice (which have ratios of around 1.04 and 1.12).
- While the profiles in Figure 1: Typical public transport patronage ramp-up profiles from service changes illustrate the typical pattern of response to improvement initiatives, some exceptions to this pattern have been identified. For example, in one case of bus route restructuring on an area basis, patronage was found to decrease initially (over the first few weeks), before reverting to a similar growth profile to those in Figure 1: Typical public transport patronage ramp-up profiles from service changes and soon exceeding the previous patronage levels.

From the foregoing, in relation to the ramp-up phenomenon, we conclude that:

- Patronage 'ramp-up' associated with public transport initiatives is a significant effect that should generally be taken into account in demand forecasting and related economic appraisal. It is also important to the perception of the initiative in the early years after completion, so ramp-up experience in similar initiatives will be relevant
- However, while the ramp-up issue is important, as noted by Flyvbjerg (2005): "In cost-benefit analyses, errors in the ramp-ups are likely to have a relatively minor impact on the total present value of benefits as compared to errors in the forecast total demand".
- 'Ramp-up' tends to be most significant (i.e. slower) for major initiatives which involve complex changes to public transport services over an extended area or corridor. For more minor initiatives (e.g. bus service changes on existing routes), ramp-up effects tend to be less significant (faster) but may still be of relevance for shorter-term forecasting and budgeting purposes.
- Of the three typical ramp-up profiles analysed, only the slowest (for major initiatives) seems to be broadly consistent with the international evidence, suggesting that long-run responses (after a period of typically 7 to 10 years) are around twice the short-run responses (after 12 months). The other profiles indicate much lower long-run: short-run ratios.
- In the absence of evidence to the contrary, the 'ramp-up' profiles for the different initiative categories in Figure 1: Typical public transport patronage ramp-up profiles from service changes and Table 4 should be adopted.
- There remains a need for further post-implementation analyses on this topic to provide improved future estimates of ramp-up profiles for the full range of categories of public transport initiatives of relevance to Australia.

2.4 Public transport demand annualisation factors

Economic appraisals require estimation of benefits to transport users over the full year, which are based on passenger journey (or possibly passenger boarding) estimates for the full year. Typically, demand estimates for public transport initiatives are based on demand model outputs, which commonly relate to data for only one period (e.g. weekday AM peak) or for two periods (e.g. weekday AM peak plus weekday inter-peak period). Where estimates are based directly on patronage (or journey) data rather than model outputs, such data are often also available for only limited periods (e.g. weekday counts only). Thus, the economic analyst is commonly required to apply 'annualisation' factors, to convert patronage data or demand model outputs from limited periods into annual demand and user benefit estimates (typically separated between peak and off-peak periods for estimation of benefits).

In the case of road traffic, the concept of average annual daily traffic (AADT) is often used, whereby the AADT figure represents the average daily figure over the whole year (i.e. annual traffic volume/365), allowing for weekends, holidays, seasonal variations etc. As there is no similar, widely-accepted concept for public transport analyses, the analyst has to develop appropriate annualisation factors to apply to whatever survey or model data are available. To assist in this task, Table 5, Table 6 and Table 7 provide data on the typical distribution of urban public transport demand over a typical weekday (Table 5), between the days of the week (Table 6), and between the different day types in the year (Table 7).⁸

In applying this (or similar) data to estimate total annual demand and user benefits, the following points should be noted:

- The unit benefits (per trip) for public transport initiatives (and road traffic initiatives) are generally very different in peak and non-peak periods, and so any economic appraisal should analyse the demand separately for these different periods.

⁸ The data in these three tables is based on the average of figures for SE Queensland (provided by Queensland DTMR/TransLink) and for Hobart (provided by Metro Tasmania P/L).

- In relation to this point, typically model outputs for public transport economic appraisal would be for a minimum of one peak period (e.g. weekday 0700–0900) and one off-peak period (e.g. weekday 0900–1500). In such a case, the annual benefits applying to peak conditions would typically factor the weekday 0700–0900 patronage to also allow for patronage in the PM peak; while the annual off-peak benefits would allow for demand at all time periods of the week apart from the two weekday peak periods. As a variant on this, some model outputs may cover the PM peak separately, but it is rare for model outputs to address evening or weekend situations separately – although that would be more accurate. Another variant may be a model that relates to the full weekday (or say weekday 0700–1900), without any peak vs off-peak disaggregation. This makes the analyst's task more difficult in deriving full-year benefits, even if unit benefit figures are available separately for peak and off-peak periods.
- Model results are generally expressed in terms of public transport 'journeys' (between origin and destination) and the user benefit measures relate to such journeys. Public transport survey data are generally expressed in terms of 'boardings', where a proportion of journeys involve more than one boarding (due to the need to transfer between services). This needs to be kept in mind when reconciling model journey outputs with public transport operator patronage data.

Table 5 Distribution of weekday public transport demand by time period

Time period	Share of demand	Average hourly demand share ⁽¹⁾ Demand/hour
00:00 to 06:59	3.7%	1.9%
07:00 to 08:59	22.4%	11.2%
09:00 to 11:59	15.6%	5.2%
12:00 to 14:59	18.3%	6.1%
15:00 to 15:59	13.1%	13.1%
16:00 to 17:59	18.5%	9.3%
18:00 to 21:59	7.4%	1.9%
22:00 to 23:59	1.0%	0.5%
Total	100.0%	

(1) Figures in third column derived from second column by dividing by length of time period in first column (period 00.00 to 06.59 taken as 2 hours).

Table 6 Distribution of working weekday public transport demand by day of week

Time period	Number per annum	Share of total weekday demand
Monday	47	18.5 %
Tuesday	50	20.7%
Wednesday	52	20.5%
Thursday	51	20.3%
Friday	51	20.0%
Total	251	100.0%

Table 7 Distribution of annual public transport demand by day type

Time period	Number per annum	Share of total annual demand	Share of total annual demand per day
Average working weekday	251	87.9%	0.350%

Time period	Number per annum	Share of total annual demand	Share of total annual demand per day
Saturday	52	7.0%	0.135%
Sunday	52	4.1%	0.079%
Public Holiday	10	1.1%	0.110%
Total	365	100.0%	

For example, the annualisation factor to convert average working weekday results to annual results = $251 * 100 / 87.9 = 285.6$.

2.5 Risk and uncertainty in public transport demand estimation

Analysts need to use the best available data to support their demand forecasts for all types of transport initiatives. This includes public transport in which there is a general tendency for optimism bias, with substantial over-estimation of patronage demand being common (Flyvbjerg et al. 2003, 2006).

The financial risks associated with optimism bias are especially a problem for initiatives involving major 'sunk cost' investments in public transport infrastructure. Sunk costs, such as fixed infrastructure, cannot be reversed. On the other hand, non-sunk costs such as buying an extra bus can be reversed by selling the asset. The cost penalty of incurring sunk costs is therefore much higher than incurring non-sunk costs. Accordingly, if optimism bias leads to a bad investment decision, the associated cost penalty (i.e. financial risk) is greater with sunk costs than non-sunk costs.

Analysts can use various approaches to reduce the risks of inaccurate demand forecasts being provided, which in turn feed through to inaccurate estimates of public transport investment costs, operating costs, fare revenues and hence the economic and financial justification for the project. The most useful approaches will very likely be dependent on the approach used in preparing forecasts. Where forecasts have been prepared using formal modelling methods, often based on multi-modal metropolitan/regional transport ('four stage') models, the following should be considered to minimise forecasting risks:

- **Back-casting.** This involves applying the proposed demand forecasting methodology to 'back-cast' demand for the corridor concerned and for other public transport initiatives implemented elsewhere. This process will establish whether the proposed methodology is able to represent observed patronage outcomes in other (broadly similar) situations. If the methodology is deficient in this regard, it should be reviewed and adjusted as appropriate.
- **Adoption of best practices.** Demand modelling methods should be consistent with 'best practice' developed and applied internationally. While a formal 'best practice' manual on demand forecasting for major public transport initiatives does not exist internationally, a number of publications (and case studies) can provide valuable advice in this regard. One example is the UK Department for Transport WebTAG manual (the UK equivalent of these Guidelines). Advice from recognised experts on this topic can also be valuable.
- **Peer review.** Relating to the above, for major projects (at least), a formal independent peer review of modelling and appraisal methodology and its application to the initiative is likely to be very valuable. For maximum effectiveness, the peer reviewer should be involved at several stages in the demand modelling/economic appraisal task, rather than only towards the end (when it may be too difficult and/or too late to make major changes).
- **Learning from post-completion evidence.** Valuable lessons may be learned from post-completion evaluations of somewhat similar initiatives implemented elsewhere in the past. Unfortunately, relatively few comprehensive post-completion evaluations of major urban public transport initiatives are available worldwide, although this situation is gradually improving.
- **Integration of demand forecasting and economic appraisal aspects.** In studies of several major Australian public transport initiatives over recent years, the demand modelling/forecasting aspect and the economic appraisal aspect have been undertaken separately rather than in an integrated manner. In

some of these cases, the economic appraisal consultant has been appointed after the demand modelling consultant (or in-house team) has completed their task, giving no opportunity to achieve consistency across the two aspects. This is an undesirable practice, liable to result in substantial deficiencies in the economic appraisal and its results, as the modelling outputs may well not have been designed with the appraisal task in mind. In the case of major public transport investment projects in particular, we recommend that demand modelling/forecasting and economic appraisal aspects are designed and undertaken as a fully integrated group of tasks.

- **Comparison of forecasts using alternative methods.** It is good practice wherever possible to cross-check any model-based demand forecasts against less detailed estimates made using simpler methods, particularly those based on elasticity and related methods. Such comparisons should be an integral part of model validation and calibration procedures and also applied to the results for the specific initiatives being appraised.

The above comments apply primarily to demand forecasts being prepared using multi-modal or public transport specific network-based models, and hence principally to the more complex and more costly initiatives.

In cases of simpler initiatives, as noted above, the inherent financial risks and the extent of 'sunk' costs associated with smaller public transport initiatives are very much less than those involving major infrastructure investments that have a large component of 'sunk' costs). Notwithstanding that, for smaller initiatives, methods not involving formal modelling are most commonly used, including in particular the elasticity-based (including diversion rate) methods outlined earlier. These methods have the merits that:

- They start from a firm base of existing public transport demand (boardings and/or journeys) data
- They apply 'elasticity' and related evidence that is based directly on observed behavioural changes in similar situations, and for which the behavioural relationships have been shown to be readily transferable (between cities and countries, for compatible market segments).

Provided the evidence summarised earlier on direct elasticities, diversion rates and ramp-up profiles is appropriately applied, forecasting risks associated with using these methods should be mitigated to a large degree.

3. Cost-benefit analysis methodology

Cost benefit analysis (CBA) is central to the ATAP appraisal system as explained in Part F3. The general features of a transport CBA are set out in Part T2 of the Guidelines. This chapter addresses matters related to the application of CBA that are specific to public transport initiatives.

3.1 Specifying the Base Case and the Project Case

An appraisal investigates the merit of a proposal relative to some alternate approach (i.e. the Project Case relative to the Base Case). The general features of the Base Case and the Project Case are described in Chapter 1 of Part T2 of the ATAP Guidelines. It is of note that the Base Case impacts the results of an appraisal as much as the Project Case, so careful consideration is needed in defining and analysing both cases.

There is generally no difference in principle in the work needed to specify the two cases for public transport initiatives compared with that for other transport initiatives. The principal issue in practice is the need to address the operational aspects of public transport initiatives because of their considerable impact on the quantity and cost of public transport that needs to be provided. This requires particular attention to identifying and estimating operating and maintenance costs over the duration of the appraisal period in the Base Case and also the Project Case. The following sub-sections provide brief comments on matters of particular importance to public transport initiatives.

3.1.1 Base Case

The Base Case (see part T2 Section 1.6) is the situation expected if the proposed initiative described in the Project Case is not implemented. It typically represents the 'business as usual' situation and is sometimes referred to as the 'do minimum' situation. The issues are generally the same as those relevant to the Project Case:

- The Base Case should include a continuation of the existing services or a variant of these services that is a realistic alternative to proceeding with the initiative considered in the Project Case.
- As with the Project Case, the Base Case should include capital and recurrent expenditures needed over the appraisal period. Allowance can be made for anticipated changes that might reasonably occur, such as a need to upgrade existing infrastructure to enable services to continue and a need to add capacity to cater for rising patronage associated with population growth, provided the cost is modest (see footnote 2).
- Estimates of operating and maintenance costs should reflect the costs of sustaining the infrastructure that will be present in the Base Case. It is likely this infrastructure will be older and have higher unit maintenance costs than would occur in the Project Case.

Where Base Case assets are likely to become technologically obsolete, or to reach the end of their economic life during the appraisal period, allowance should be made in the Base Case for their replacement by assets as similar in function as possible. Railway signalling systems are an example of a type of asset for which technological progress could require updated technology when replacement becomes due.

3.1.2 Project Case

The Project Case is the situation expected if the initiative is implemented. Usually there are multiple options available for solving a problem, so more than one project case should be assessed. Some matters particularly important to public transport initiatives are:

- A need to take account of the full range of infrastructure associated with the initiative, such as that described in Table 8.
- In considering different options, also consider progressing different modes such as new bus services followed some years later by rail, subject to the demand forecasting profile.
- In addition to any infrastructure to be provided as part of the initial investment, there is a need to take account of additional fixed assets and rollingstock that may be required to carry forecast growth in public transport patronage during the remainder of the appraisal period (see footnote 2). Re-investment in rollingstock and other infrastructure that reaches the end of its useful life before the end of the appraisal period also needs to be taken into account.
- Project specification is a particular challenge in relation to public transport 'network initiatives', which can have ramifications on the wider public transport network. These impacts may not always be readily apparent. The impacts need to be carefully identified, including those that may occur some distance away from the location of the initiative itself, such as a need to upgrade electricity supply or track capacity in a rail network.
- Complementary development needs should be taken into account, such as the need to develop feeder bus services to a new or upgraded rail line.
- There is a general historic experience of public transport projects costing more than initially estimated and carrying fewer passengers than anticipated. Particular care is needed in specifying the Project Case so that costs and demand estimates are as complete and accurate as possible. Risk and uncertainty are addressed further in Section 4.

Table 8 Public transport infrastructure categories

Category	Elements
Systems infrastructure	Management centres such as network control centres; signalling; communications; rollingstock storage and maintenance; fare systems; signage; etc.
Network infrastructure	Rail networks; bus lanes; etc.
Nodal infrastructure	Stations; interchanges; parking stations; etc.

The quality of cost estimates (see Part O1 Cost Estimation) can be improved by breaking down initiative costs in a structured way. This is desirable for three reasons:

- Different assets have different lives and therefore different residual values at the end of the appraisal period
- The operating and maintenance costs associated with different elements of infrastructure are likely to vary
- A more detailed breakdown enables the make-up of infrastructure costs to be better understood, particularly for:
 - Minimising the risk that costs are forgotten
 - Enabling attention to be focused on areas of greatest significance to the total costs of the initiative
 - Permitting closer attention to be paid to areas where there are uncertainties and risks in estimating the costs of an initiative.

Where possible, work breakdown structures should follow a similar architecture and format to those used in the asset management systems of the organisation that will take ownership of the infrastructure. This provides several advantages:

- It enables the appraisal to use maintenance schedules and costs that are consistent with those used elsewhere in the organisation (provided these are appropriate)

- If the initiative proceeds, the organisation will find it easier to incorporate it into its asset management system
- It should facilitate post-implementation monitoring by making it easier to access cost information.

Two other matters require careful treatment:

- The Project Case could include non-core improvements that could, at low cost, be implemented in the Base Case. Thus, for example, feeder bus services associated with a new or improved train line in the Project Case could involve a re-orientation of the bus services to serve the train line as well as a more general overhaul of the services to provide other benefits.
- There will be occasions where there is some other proposal not already 'committed' (i.e. with contracts for implementation) that is not a formal part of the proposed initiative, but which may affect the merits of the initiative being appraised.

In these cases, the appraisal should consider three cases: (a) the Base Case; (b) an Alternative Scheme (the Base Case plus, with regard to the above examples, the bus services that could be improved in the Base Case or the uncommitted proposal); and (c) the Project Case. This allows the merit of the initiatives in the Alternative Scheme and the incremental merit of the additional initiatives in the Project Case to be separately appraised. The aim of this approach is to ensure the costs and benefits of each initiative are separately identified. In this manner, for example, the benefits that could be obtained by making general improvements to bus services are benefits that could be obtained without implementing the formal initiative in the Project Case appraised separately, and associated costs and benefits are not attributed to the project.

3.2 Identifying options

The ATAP Framework (see A1 Overview) sets out a general approach to strategic planning and the identification of alternative potential initiatives that addresses identified problems and which then need to be subject to appraisal. This section notes some unique matters related to identifying problems associated with public transport that may necessitate an intervention, followed by the identification of potential responses.

3.2.1 Problem identification

Public transport agencies commonly have a range of performance indicators that show their performance related to the demand for public transport services and the provision of services (see Chapter 7). Problems that can be identified include overcrowding (or underloading) of services, inadequate access to public transport, poor schedule adherence, slow travel times and special needs of passengers. These problems can be identified on a continuing basis by using 'exception' reporting of routine statistics and through interrogation of the indicators as part of some specific study.

Identified problems also need to be placed in context (e.g. to identify relevant intermodal factors) and be related to the transport system objectives (see Part F3).

3.2.2 Option identification

Alternative means for addressing the identified problems then need to be identified (see Part F3). A broad view should be taken to the options, with consideration given to regulatory, governance and operational initiatives as well as capital investment. An initial list of options should be identified, and then screened to identify the options with the greatest potential.

Considerable care is needed in the case of public transport to avoid a sole focus on a particular technology or other preferred solution. While there are some clear roles for different modes of public transport as a means for addressing problems, there is also a considerable degree of overlap in their capacity to

accommodate potential patronage demand. A broad indication of the capacity for some typical modes is set out in Table 9.⁹

Equally important to the mode is the circumstances in which the mode is used. For example, a dedicated right-of-way allows a mode to carry much higher volumes of passengers, while buses can be used on steeper grades than rail-based modes. There is also a need to take account of the costs of the various modes, with the capital costs of rail-based modes generally likely to be higher than for bus and the reverse often occurring with regard to operating costs. Finally, different modes offer different degrees of adaptability and scalability and may provide characteristics which mitigate the possible effects of key uncertainties affecting the initiative.

Typical capital and operating costs for public transport modes are discussed further in Chapters 6 and 7 of this Part.

Table 9 Indicative vehicle and corridor capacities by mode

Mode	Passenger occupancy (per bus or trainset)			Maximum vehicle flow	Passenger flow (per hour per direction)	
	Seated	Stand- ing	Total	(No. of buses or trainsets per hour per direction)	Common minimum patronage	Maximum capacity
Street bus (rigid bus, no bays for bus stops)	40	24	64	105	-	6,700
Kerbside bus lane (rigid bus, with bays for bus stops)	40	24	64	150	2,000	9,600
Bus rapid transit (articulated bus, exclusive off-street right-of-way)	70	32	102	300	4,500	30,600
Light rail transit (set of 2 articulated cars, on-street in own lane)	120	260	380	36	4,500	13,700
Light rail transit (set of 3 articulated cars, exclusive right-of-way)	180	390	570	46	8,000	26,200
Metro (6-car set)	300	1,080	1,380	36	13,000	49,700

Source: Drawing on Deng & Nelson (2011), Fernandez & Planzer (2002), IEA (2002), TRB (2003), Vuchic (2005) & Zhang (2009).

3.3 Other matters

This section addresses four other matters that are discussed more generally in Part T2 of the Guidelines, but for which some additional, specific comment is needed with regard to the appraisal of public transport initiatives.

3.3.1 Appraisal period

For general guidance on the appraisal period see Section 2.4 of T2. The section states that “It is usual to assume a 30-year life for road initiatives (except bridges, which have much longer lives) and a 50-year life for

⁹ The passenger occupancy total figures given in Table 9, as drawn from the documents noted, generally approximate to maximum vehicle capacities (typically based on 4.0 standees/m² of net floor area). These are significantly higher than practical capacities appropriate for service planning purposes, which are given in chapter 6 (Table 30).

rail initiatives". That guidance is equally applicable to public transport initiatives. However, public transport initiatives can include a broader range of works than is usual for other projects (e.g. road), including various civil infrastructure, electrical and mechanical equipment, and rollingstock. These various assets will have differing asset lives.

These matters mean it will be common that no single appraisal period will equate to the life of the assets required for a public transport investment project. In those cases, a residual value is included at the end of the appraisal period, to approximate the benefits generated by those assets that have a life beyond the end of the appraisal period. Guidance on estimating residual values is available in Section 3.3 of T2.

3.3.2 Change in benefits over time

The approach to taking account of changes in benefits over time is described in Chapters 6 to 9 in T2. It covers matters such as the effects of population growth and rising traffic congestion on travel demand and travel conditions in the Base Case and Project Case. There are no specific differences that should be taken into account relating to public transport initiatives other than the need, if relevant, to take account of ramp-up in patronage demand in the Project Case, and hence the ramp-up in benefits that occurs as people gradually change their travel behaviour. Patronage ramp-up is discussed in Section 2.3 above.

3.3.3 Benefit–cost ratio

As indicated in Section 10.4 in Part T2 of these Guidelines, the benefit–cost ratio (BCR) should be calculated in two different ways:

- With all supply costs incurred by government being included in the denominator (i.e. the 'cost'), and the consequences of these capital and operating costs included in the numerator (i.e. the 'benefit') (BCR1), and
- With only the initial capital (investment) cost being included in the denominator, with all other effects in the numerator (described as benefits that occur after the initiative has commenced operation, noting that some individual effects may be negative i.e. disbenefits) (BCR2).

Both BCR definitions can be used to indicate whether the project has a positive net present value. BCR2 is the appropriate measure for comparison of projects in a capital-constrained environment.

Only BCR1 can be used for initiatives that involve no investment expenditure such as an increase in the quantity of service that is able to use existing fixed infrastructure and rollingstock. For BCR2, the absence of investment costs means a zero denominator, but as the project would not be competing with other projects for investment funds, BCR2 is not required.

4. Benefits of initiatives

A CBA measures net benefits as increases in ‘social welfare’ of the nation. This can be measured in two equivalent ways (see discussion in Chapter 6 of T2):

- As the total increase in willingness to pay less the increase in resource costs, or
- As the sum of the sum of the increase in welfare (or net benefits) to the various parties affected (of an initiative as the sum of the following components (IA, 2017):
 - The change in consumer surplus (CS) – user benefits
 - The change in producer surplus (PS) – net benefits to service providers and government
 - The change in third party (externality) effects.

Chapters 6 and 7 of T2 discussed in detail the measurement of the user benefits using the change in willingness to pay less the change in user resource cost, and also the change in consumer surplus (measured with the rule-of-a-half) plus any required resource correction. Table 2 therein provides formulae for estimating user benefits — and apply here.

Chapters 8 and 9 of T2 discussed the measurement of changes in externality effects.

The principles and formulae in Chapters 6 to 9 of Part T2 continue to apply here.

This chapter provides complementary guidance for use in cost-benefit analyses of public transport initiatives. Analysts should draw on both of these sources when undertaking an appraisal of an initiative.

Both road and public transport initiatives can affect public transport travel conditions. The effects of these changed conditions should be taken into account in appraisals.

The benefits of initiatives that improve public transport consist of:

- User benefits to:
 - People who use public transport in the Project Case, which will include people who used the equivalent public transport service in the Base Case (if it existed)
 - People attracted from other public transport services, drivers and passengers attracted from car, and users of other modes such as bicycle and pedestrians, and
 - Generated public transport travel
- Benefits to those who continue to use private road vehicles in the Project Case, in the form of reduced traffic congestion from diverting some former car-drivers to public transport — or, to the extent that additional road travel is generated by the improved traffic conditions, the benefits gained from this additional travel
- Benefits that accrue to the entire community such as reduced environmental pollution
- Benefits from productivity improvements in the economy that are not captured by standard cost benefit analysis, which are generally called wider economic benefits (WEBs)
- Benefits to the community from having improved public transport available for possible future trips not yet anticipated, and simply to have access to it even if it is not used
- Other benefits from improved accessibility, such as the benefit to people who would otherwise have more limited access to transport
- Changes in producer surplus accrued by service providers and governments.

The first two of the benefit categories above are referred to as user benefits. They are estimated here as the change in consumer surplus of the various groups of travellers, with adjustments made to take account of travellers’ misperceptions of the resource costs of their travel.

The following sections of this chapter address:

- The implications of misperception of the resource cost of travel for the estimation of economic benefits (Section 4.1)
- The estimation of changes in users' consumer surplus, which will generally be the largest benefit item (Section 4.2)
- Resource corrections (Sections 4.4 and 4.5) required to properly account for resource costs
- Discussion regarding the estimation of other categories of benefits (Sections 4.5 to 4.10)
- A checklist of the various benefits (Section 4.11).

Default unit benefit values for parameters specifically related to the appraisal of public transport initiatives are presented in Chapter 5 for analysts to use in the absence of specific data relevant to the initiative they are appraising. Some additional parameter values are also set out in this chapter.

4.1 Misperception of travel costs

Economic appraisal is simplified considerably if prices are equal to marginal social costs and travellers fully perceive these costs. Neither of these situations occur for transport. Part T2 of these Guidelines discusses, in general terms, how to estimate benefits where prices or perceived costs differ from marginal social costs. The consideration of benefits in the remainder of this section is therefore based on the normal situation in which there is a divergence between marginal social cost and the financial cost of travel, and between the financial cost of travel and travellers' perceptions of these costs.

The general principle for the valuation of benefits is that they should be based on the revealed willingness of users to pay to gain the benefits. The rationale is that the value of benefits to users should be that perceived by the users, and that it would be sub-optimal to spend more than this amount to gain the benefits. Economic optimality is achieved when the prices that people must pay are equal to marginal social costs and travellers take account of these costs when making travel decisions. However, divergences from this optimal situation result because prices in the transport sector are not set on the basis of marginal social costs (it would be only by chance that the financial price of a transport service was equal to this)—there are tangible impacts from initiatives that users do not perceive, but which still need to be taken into account in economic appraisals.

The perceived cost (sometimes also called the 'behavioural cost' because of its influence on behaviour) will include financial costs that travellers take into account when making travel decisions as well as the value of their travel time. The financial costs can include tolls, fares, some vehicle operating costs and parking costs. Computerised travel demand models are based on perceived travel costs, and thus benefits based on data in travel models are based on perceived values. However, the benefits in an economic appraisal need to be based on resource values (i.e. the underlying economic value of the resources associated with the travel). There is a need to take account of this difference.

Motorists do not correctly perceive the full economic costs of their travel for the following reasons:

- When making travel decisions, motorists fail to take account of all of the actual financial costs they incur because of poor recollection of costs. For example, a motorist may replace tyres every few years, and forget the wear and consequent cost of tyre use when making individual trip decisions. Similarly, they may not take account of use-related depreciation of their vehicle, and annual registration and insurance charges may be treated as a sunk cost. Further, motorists may not correctly perceive the cost of fuel when making travel decisions because of the time separation between paying for the fuel and using it.
- The financial costs that motorists pay include taxes, which are transfer payments that do not represent use of any resources. Hence, even if motorists fully understood the financial costs of making their trips, they cannot know the resource cost because the tax component of the financial costs is not explicit.

- Car use imposes costs on others that are not explicitly charged for. These costs, known as externalities, include pollution, congestion and the components of crash costs that are not recovered through insurance.

It is generally accepted that public transport users are more likely than motorists to take account of the financial costs they incur in their travel because they pay fares when making trips (or within a reasonably close period if using some type of prepaid ticket). However, like motorists, they will be unaware of the external costs their travel imposes on others and of the presence of taxes and subsidies in their fares. They are also unlikely to take account of the cost of crashes that involve public transport (which are very low though not zero).

The perceived costs commonly incorporated in travel demand models typically include:

- For car travel - the value of their personal travel time, and fuel and parking costs and any toll charges
- For public transport - travel time and fares.¹⁰

As a result, the calculation of user benefits that are based on these perceived costs does not indicate the economic value of the benefits. The difference between perceived user benefits and their economic value can be taken into account in an economic appraisal through 'resource corrections'. This matter is discussed further for transport generally in T2 Section 6.4 and, specific to public transport, in Sections 4.3 and 4.4 below.

The next section in this chapter discusses the calculation of the change in consumer surplus for travellers, which is based on perceived costs. Account of resource corrections and other effects of a public transport initiative are considered in subsequent sections.

4.2 Estimating changes in consumer surplus

The largest component of benefits of an initiative will generally be changes in consumer surplus for travellers. The change in consumer surplus comprises:

- The increase in consumer surplus gained by people who use public transport in the Base Case and Project Case (*'existing' trips*), and
- The consumer surplus gained by *new users* of public transport, which in turn includes:
 - *Generated trips* (i.e. travel not previously made at all), and
 - *Diverted trips* (i.e. trips that were made in the Base Case but which are attracted to the improved public transport in the Project Case). (For definitions, see A2, Glossary 2 — Traffic Types)

4.2.1 Estimation methods

These benefits can be calculated in four ways:

- Method 1: Simple rule-of-a-half manual method
- Method 2: Rule-of-a-half manual method using a multi-modal demand model
- Method 3: Numerical integration – modified rule-of-a-half method using a multi-modal demand modal
- Method 4: Logsum method derived directly from a multi-modal model.

¹⁰ For car and public transport travel, travel demand models include in travel time both in-vehicle and out-of-vehicle time. These are captured in the measure of generalised time which also accounts for a range of intangible influences on travel choices such as convenience, reliability, crowding. See ATAP Part T1 for detailed discussion.

These methods are described in Appendix B. Method 1 will generally only be appropriate where an initiative has very limited impacts. Methods 2, 3 and 4 all draw on data from a travel demand model.

Central to measuring the change in consumer surplus using any of these methods is estimation of the change in generalised cost faced by public transport users between the Base Case and Project Case. Chapter 5 discusses the range of factors that determine generalised cost, and their estimation using a set of default parameter values.

4.2.2 Summary and roles of methods

Method 1 is of use only where a public transport project has no effects on travel demand other than a shift between public transport services. In other cases, it is generally necessary to use a multi-modal urban travel demand model to establish changes in travel demand that will result from a public transport initiative or a road initiative that affects demand for public transport. In such cases, analysts can use methods 2, 3 or 4. The best roles for the four methods are summarised in Table 10.

Table 10 Role of various approaches for estimating changes in consumer surplus

Method	Best use	Notes
1. Simple rule-of-a-half manual method	Can only be used in simple situations such as improvement to a local service that that does not change the origins and destinations of trips or the mode of transport used.	Cannot be used where a public transport initiative will have substantial effects on travel demand.
2. Rule-of-a-half manual method using multi-modal demand model	Best used when: - Travel demand changes significantly, including changes in the quantity, mode and location of trips - There is a desire for greater transparency by estimating benefits separately from the travel demand model.	Requires travel demand origin-destination matrices and skims from some form of travel demand model.
3. Numerical integration – modified rule-of-a-half method using multi-modal demand model	Best used when: - The initiative involves introduction of a new mode - The demand curve in the region of the change in travel demand is likely to significantly deviate from a straight line - The demand model is <i>not</i> logit-based.	
4. Logsum method derived directly from multi-modal demand model	Can be used when: - The demand model <i>is</i> logit-based - The initiative involves introduction of a new mode - The demand curve in the region of the change in travel demand is likely to significantly deviate from a straight line.	Requires a logit travel demand model

The logsum method has been used only to a limited extent in Australia, though it has been used more extensively elsewhere, particularly in the USA. The method is theoretically sound, though its limited use in Australia means there is a need for practitioners to develop expertise in its use and for decision-makers to gain confidence in its results. Hence, there is a danger in the 'leading edge' departing too far from conventional practice. Although the Rule-of-a-Half approximation, and the basic concept of Consumer Surplus, are simplifications of the underlying theory, they do retain substantial appeal in terms of their relative ease of application, reasonable interpretability and acceptable accuracy (Bates 2003:36).

The *logsum* method is especially valuable in the three instances described above; that is:

- Where the project involves introduction of a new mode
- Where the demand curve is likely to significantly deviate from a straight line.

4.2.3 Recommended practice

It is recommended that:

- The rule-of-a-half methods (1, 2 and 3) continue to be used as the primary methods in practice
- Use of the logsum method is acceptable when using a logit discrete choice multi-modal demand model provided that:
 - The user is experienced with using logit models and is aware of the issues associated with logsum calculations (e.g. the logsum from the utility models can be readily estimated and the marginal utility with respect of income is available – see further discussion in Appendix C), but that
 - Estimates using the rule-of-a-half approach (methods 2 and 3) also be presented at the same time as cross-checks / sensitivity tests of the reasonableness of the logsum results. This is also a means of developing confidence of decision-makers in the reliability of the logsum method
- Analysts be encouraged to investigate use of the *logsum* method when using a logit travel demand model (in line with the above points) as a means for achieving a wider understanding of it, developing capacity for its use, and for increasing the confidence of practitioners and decision-makers in its results
- A gradual approach be taken to the implementation of the use of the *logsum* method given its limited use in Australia to date, and that it is likely to be considered complex by a range of practitioners.

4.3 Fully accounting for changes in resource costs

If travellers based their travel decisions on the full resource costs of their travel, the calculation of consumer surplus described in Section 4.2 would fully record the benefits accruing to travellers from the shift to public transport. In practice, this will rarely be the case because, for example, the presence of taxes and subsidies means that travellers are not readily able to perceive the resource costs of their travel.

Accordingly, an adjustment is required to take account of the full resource value of the benefits that occurs when people transfer from another mode to public transport. This adjustment, or resource correction, reflects the difference between the benefits based on the perceived costs and those based on the associated resource costs of diverted and generated travel (see Section 6.4 of T2 for a more detailed consideration of this matter). Where the perceived cost exceeds the resource cost, the resource correction is an additional benefit; where the resource cost exceeds the perceived cost, the resource correction is a disbenefit. The general formula for the resource correction for diverted and generated travel, taken from T2, Section 6.4 is:

Resource correction = (perceived (average) cost – average social generated cost) x quantity of diverted and generated traffic

which can be expressed for public transport as:

Resource correction = (perceived cost of travel – resource cost of travel) x quantity of diverted and generated travel.

The calculation of the resource correction can be performed outside of a computerised travel demand model. It will draw on the aggregate amount of travel by each mode indicated by the model, the perceived travel cost parameters used in the model (e.g. the perceived value of travel time, mode-specific factors, fares, vehicle use costs and parking costs) and the resource cost of travel that is estimated by the analyst or default values set out in these guidelines. The perceived travel costs included in travel demand models may vary between models, and so default values for perceived travel costs cannot be provided. Finally, it is noted that different people may have different perceptions of the same cost of travel. However, as with other items in travel demand models and appraisal, average values for the community as a whole are used except where average values for population sub-groups are used.

In the remainder of this chapter, various cases are discussed where travel costs are commonly misperceived and where, therefore, a resource correction is needed. For completeness, all possible needs for a resource correction are 'addressed, though it is noted that in practice no correction will be required in some instances because the effect is very small or because users perceive all resource costs.¹¹

4.4 Accounting for public transport fare revenue

Additional public transport users will generally pay a fare. The literature provides two approaches for accounting for this revenue in an appraisal.

4.4.1 Change in producer surplus

The traditional economic literature recognises increased fare revenue as a benefit to the service provider. The increase in revenue, minus the increase in operating costs, combine to produce an increase in 'producer surplus' (PS) (IA, 2017).

That is:

$$PS = (F - AC_p) (Q_2 - Q_1)$$

where F is the average fare per public transport trip

AC_p is the unit operating cost of providing relevant public transport services

Q₁ and Q₂ are the number of public transport trips in the Base Case and Project Case respectively.

Note that the fare and GST paid by users is a transfer between users and the service provider. The inclusion of the change in producer surplus reflects this by offsetting the negative impact of fares and GST on the additional public transport users when measuring consumer surplus.

For generated trips and trips diverted to public transport, good and services (GST) tax is included in fares. It is part of perceived cost and therefore part of the user's willingness to pay. It is a benefit to public transport users that is passed on to the government, the same way the rest of the fare is a benefit passed on to the public transport operator. In the resource correction method discussed below, GST is included in the resource correction calculation as part of the 'perceived cost of travel'.

4.4.2 Resource correction

Some public transport literature provides an alternative approach. It recognises the fare is part of the perceived cost of travel for the purpose of making mode choice decisions, which results in the fare being treated as a cost when calculating consumer surplus. Moreover, the fares paid will commonly understate the resource cost of providing public transport (at the margin, to accommodate the additional user). Hence, when consumer surplus is calculated using a perceived cost that includes fares it is necessary to add fares back as a category of benefit to derive the total resource benefit from increased public transport use. (This would not be the case where fares were not included in the calculation of consumer surplus.) The resource costs of

¹¹ It is noted that no allowance was made in Section 4.4.1 for a resource correction for existing public transport users. Such a correction would be needed if, for example, a uniform resource value of travel time was adopted for users of all transport modes given that the perceived value of travel time varies between modes. This would become a complex adjustment, and it is recommended that such an approach not be used. Rather, concerns regarding equity that may arise from the use of different behavioural values of travel time for different modes should be addressed elsewhere in the Appraisal Summary Table described in F3.

providing public transport (capital and operating) are included elsewhere, as costs, in an economic appraisal (see Section 6).

4.5 Safety improvements

Changes in the number and costs of road crashes from reduced car use as motorists and car passengers shift to public transport should be estimated in the conventional manner set out in Step 8 in Volume T2 of these Guidelines. Default values for crashes are set out in PV2.

Crashes still occur with public transport, as indicated by claims made against public transport agencies by passengers and damage caused to public transport and other vehicles. These costs need to be added as an extra item if they are not part of the cost of travel perceived by public transport users (as is usually the case) or if they are not included in estimates of public transport operating costs. Data on crash costs can be obtained from public transport agencies using actual data on crash rates and costs that they incur.¹²

4.6 Environmental effects

Changes in the amount of road traffic from reduced car use as motorists and car passengers shift to public transport, and changes in traffic conditions that may result from reduced car use, will achieve environmental benefits such as reduced noise and air pollution. These should be estimated in the conventional manner set out in Step 8 in Volume T2 of these Guidelines.

Public transport vehicles also have environmental impacts that impose costs on the community (irrespective of their levels of patronage). Hence, these effects also need to be taken into account in the appraisal in addition to the emissions from other modes of transport. The value of environmental externalities set out in Part PV5 of these Guidelines should be used for the estimation of environmental benefits that result from public transport initiatives.

4.7 Other benefits for people shifting to/from public transport

The following sub-sections describe travel costs that are commonly misperceived and where a resource correction is thus needed. For completeness, all possible needs for a resource correction are addressed, though it is noted that in practice no correction will be required in some instances because the effect is very small or because users perceive all resource costs.¹³

4.7.1 Pedestrians

The resource correction in the case of a pedestrian who shifts to public transport needs to take account of:¹⁴

¹² However, note that the relevant (marginal) crash costs may be very different in situations where the additional passengers can be accommodated on existing services to those where additional services are provided.

¹³ It is noted that no allowance was made in section 4.3 for a resource correction for existing public transport users. Such a correction would be needed if, for example, a uniform resource ('equity') value of travel time was adopted for users of all transport modes given that the perceived value of travel time varies between modes. This would become a complex adjustment, and it is recommended that such an approach not be used. Rather, concerns regarding equity that may arise from the use of different behavioural values of travel time for different modes should be addressed elsewhere in the Appraisal Summary Table described in F3.

¹⁴ Note that models do not take weather into account, and are therefore likely to over-estimate active travel trips. This would over-estimate the resource correction based on modelled active travel numbers.

- **Unperceived ‘operating’ costs.** This is primarily wear on shoes, but it is possible that users perceive this cost; in which case, there is no need for a resource correction. Even if not perceived, the cost is so low that it will not materially affect the results of the appraisal and so should be ignored
- **Crash costs.** There is little evidence regarding the extent pedestrians perceive the risk of being injured or killed in a crash when making a decision to use public transport rather than walk. Where there is a limited number of pedestrians who will shift to public transport, the uncertainty about their perception of costs when making travel decisions and limited information on the likely change in incidence and cost of crashes, avoided crash costs should generally be ignored. If these factors do not apply, and the analyst has the necessary information, safety benefits can be calculated in the manner set out in Section 4.5.
- **Health (dis)benefits.** A former pedestrian who shifts to public transport will typically incur a disbenefit due to reduced exercise from walking. However, given a general awareness in the community about the need for fitness and the appropriateness of walking, it is possible that pedestrians will already perceive this disbenefit to some extent and it will thus have been partly taken into account in the estimation of the change in consumer surplus in Section 4.2. Where the change in the amount of walking is expected to be substantial, the impact should be valued taking account of the approach set out in the active travel guidance (see M4).

4.7.2 Cyclists

The resource correction needs to take account of:

- **Unperceived operating costs.** These are primarily the use of tyres and brakes and use-related depreciation of the bicycle. As for pedestrians (above), users may perceive some of the cost, but even if they do not, the cost will generally be sufficiently low that it will not materially affect the results of the appraisal and so can be ignored. The benefit can be included provided the analyst can show adequate supporting evidence that it is of material size.
- **Crash costs.** In principle, the same considerations as noted for pedestrians (above) apply. While the incidence and costs of crashes for cyclists would generally be higher than for pedestrians, it appears likely that cyclists largely perceive these costs. Therefore, no resource correction would normally be necessary.
- **Health (dis)benefits.** The same approach as described above for former pedestrians is appropriate (see M4).

4.7.3 Car passengers

- **Health benefits.** A shift of car passengers to public transport will increase the amount of walking they undertake if the walk to and from public transport is greater than the amount of walking associated with their former trip by car. Where the change in the amount of walking is expected to be substantial, the impact should be valued following the approach set out in the active travel guidance (see M4) – which recognises that the increased walking resulting from the shift to public transport has to be greater than a minimum threshold (10 minutes) for there to be any health benefits.¹⁵
- **Reduced car use.** A shift of car passengers who are chauffeured in car trips dedicated to their travel (‘serve passenger’) will reduce car use. In other cases, the reduction will be less, such as where a car driver no longer needs to take a more circuitous route to drop off/pick up a passenger who has transferred to public transport. There is little evidence on this matter, and the effect should generally be ignored. Where the change in car use is taken into account in a travel demand model, no further adjustment to benefits will be needed. If this is not the case, more detailed estimation of the change in vehicle-km of travel should be made and the resource cost of car travel applied to estimate the total benefit.

¹⁵ As stated in M4, sub-10 minute savings can be counted as benefits if robust evidence can be provided (see discussion in M4).

4.7.4 Car drivers

In the case of car drivers who shift to public transport, significant benefits in addition to those included in the change in consumer surplus need to be taken into account. These additional resource savings would typically include the following:

- **Unperceived car operating costs.** As indicated in Table 2.1 in the 2006 NGTSM Volume 5, which shows the financial, resource and perceived costs of car use, resource savings in vehicle operating costs that are not perceived include items such as the gap between the financial and resource cost of fuel and the resource cost of most other items that are a function of vehicle use such as tyres, maintenance and a share of vehicle depreciation¹⁶. Some of these effects will partially offset each other. For example, motorists over-perceive the resource cost of fuel because the financial price includes taxes, but they under-perceive costs such as tyres that are incurred only occasionally. From T2, Section 7.2, the resource correction will be a benefit equal to:

(perceived [average] cost – average social generalised cost) × change in quantity of traffic on the related infrastructure.

Since the resource cost of car travel exceeds the perceived cost and there is a quantity reduction, both terms are negative leading to a positive result — a benefit. Making both terms positive, the resource correction can be expressed as:

(resource cost of car travel per kilometre – perceived cost of car travel per kilometre) × Car-kilometres of reduced vehicle use.

- **Reduced road maintenance costs.** Less car use will reduce the cost of maintaining roads. However, the wear on roads caused by cars is very low and the effect can be excluded unless the reduction in car use is very large.¹⁷ The saving from an avoided need to build additional road capacity should be addressed in the course of addressing capital-related costs for roads and public transport that would occur in the Base Case and the Project Case.
- **Crash costs.** A shift of some car drivers to public transport can result in a decline in the number of crashes due to fewer car-kilometres of travel. This may be offset by the change in the number and severity of crashes due to changes in road traffic conditions such as higher speeds. The benefit can be valued using conventional approaches for the economic appraisal of road initiatives. Crash costs are not generally considered to be perceived by motorists when making travel decisions, so the benefit will be equal to the total resource value of the change in crash costs.
- **Environmental benefits.** Less car use reduces environmental costs broadly in line with the reduction in vehicle-kilometres of travel though with some effect from changes in traffic congestion. Data on the unit resource value of environmental benefits from reduced car use are presented in PV5. The resource value of various environmental impacts is usually expressed in relation to the quantity of vehicle use (i.e. car-kilometres of travel). The quantity of saved car-kilometres needs to be estimated to determine the monetary value of the benefit. As the resource value of environmental costs is not generally perceived by motorists, the benefit will be equal to the total reduction in car-kilometres of travel multiplied by the appropriate (marginal) unit resource value of environmental benefits.¹⁸
- **Reduced car parking.** For an economic appraisal, the principal concern is the number of car parking spaces that will be avoided as a result of the initiative, the costs of the avoided car parks and the timing of the impact. This is a complex matter. One of the following situations that are applicable to the initiative should be used to derive the benefit of reduced car parking. The possible situations are:

¹⁶ Bennett and Dunn (1990) provide evidence that a proportion of depreciation is related to vehicle use.

¹⁷ Based on the “fourth-power” rule, around 60,000 cars with two axles each carrying 0.7 tonne of mass would cause the same wear to a road as a 12 metre long two axle standard bus with axle loads of 6.5 tonnes and 10.5 tonnes respectively. Based on a cost of road damage caused by a bus of \$0.13/bus-km in mid-2014 values (see Appendix C, the avoided cost of road maintenance due to a shift from car to public transport will be negligible (at around \$2.20/million car-km)

¹⁸ Note that for some environmental factors (e.g. noise, severance) the marginal benefits for reductions in car traffic volumes may be substantially lower than the average benefits.

- i. The price of parking is perceived by car drivers when making travel decisions, and hence is included in the generalised cost of car travel used to determine the extent to which drivers divert to public transport. In this case, the change in consumer surplus will include the perceived benefit from avoided car parking. A resource correction is needed if there is a divergence between the perceived and resource cost of car parking (in the same way as for car drivers who shift to public transport while incorrectly perceiving the resource cost of their car travel). Only the difference between perceived and resource cost is taken into account in the resource correction.
- ii. The resource cost of car parking can be determined in two ways. First, the resource price can be estimated by taking the market price of car parking, less taxes such as GST and other taxes on parking spaces imposed by governments, plus any subsidy for the car parking. Where car parking is provided on a commercial basis, substantial subsidies over the long-term are unlikely. The second approach is to determine the resource cost of car parking from first principles, taking account of the value of land and construction. Analysts should where possible use values that are specific to the initiative being appraised. Default values are set out in Section 4.7.5 for instances where specific data are not available.
- iii. The price of parking is not included in the generalised cost of car travel used to determine the extent to which car drivers divert to public transport.

This may occur because, for example, there is no explicit charge for the parking or because it is paid for by an employer or through salary packaging. In this case, include the full resource value of saved car parks as a benefit. This value will vary with the circumstances, and three possible situations are identified.

- a. There is excess demand for the type of saved car park. In this case, no physical capacity is avoided and the vacated space will be used by another person. In this case, the value of the space can be taken to be equal to its market price (i.e. the willingness of another motorist to pay to use the parking space). The benefit for use in the appraisal will then be the number of car parking spaces saved multiplied by the market price of car parking (which will include taxes). However, there are some off-setting disbenefits¹⁹, and it is recommended that the net benefit should be taken as half of the market price of the car parking space. Default resource costs for car parking space are provided in Section 4.7.5 below.
 - b. The supply of car parking space exceeds demand. In this situation, the car park vacated by the former car driver remains unused and there is no resource saving in the shorter term, until additional car parking capacity is required. The benefit in this case is the same as for the previous case but will occur in the future when demand has grown to the point where all the parking spaces are used and additional car park construction would be needed.
 - c. The former car driver used ground level space on private property or on-street parking. In this case, it is likely there is no resource benefit from the reduced demand because the parking space remains and generally will not be used for another purpose other than car parking. In this case, no benefit from the avoided car park should be included in the appraisal.²⁰
- **Reduced car ownership.** Car drivers who transfer to public transport may be able to avoid the need to own a car. This will be particularly the case for regular commuters who switch from car use to public transport. Where this is the case, and given the general conclusion that motorists do not perceive vehicle depreciation or the opportunity cost of capital when making individual travel decisions, there is a need to take account of this additional, unperceived resource saving.²¹
 - However, reduced car ownership may not always occur. For example, a former car driver might leave the car for other household members to use. In this situation, the other household members perceive that

¹⁹ The motorist that uses the vacated space could, for example, be a generated or relocated trip. Matters such as the difference between the resource and perceived cost of any changes in the quantity of car travel and use of other car parking are disbenefits that offset the potential saving from the original avoided need for a car park.

²⁰ Note that, in some cases, reduced demand for on-street parking may result in the former parking spaces being used to improve traffic flow, or the land made available for pedestrians and other users.

²¹ Note, this only applies for proportion of depreciation that does not vary with vehicle use (see footnote in section 4.7.4)

they are better off by having access to the car. Alternatively, the former car driver leaves their car unused at home, resulting in there being no additional benefit.

- Given the absence of a good understanding of the effect of increased public transport use on car ownership and use, a default value is to assume the average unit benefit of reduced car ownership included in appraisals should be half the unit benefit for a former car driver who is able to avoid car ownership due to a shift to public transport (e.g. that around half of the cars are used by other household members and the ownership of half of the cars is avoided). A more specific estimate can be made if better information is available. When calculating the saving in cars that are owned, care is needed to take account of an avoided car being associated with two avoided car driver trips per day (i.e. the saving in the number of cars owned is half the number of return public transport journeys made by former car drivers). A default unit value for avoided car ownership is described in Section 4.7.5.

4.7.5 Default parameter values for benefit estimation

Avoided car parking

A recommended default resource cost (in mid-2014 prices) for a car park in a multi-storey building is \$25,000 per space excluding land, plus a further cost of about \$1,250 per annum per space for maintenance and operation of the car park. The recommended default capital cost of at-grade car parks will generally be about \$5,000 per space excluding land, with maintenance costs of about \$125 per space per annum. Operating costs for at-grade spaces will vary substantially according to the size and circumstance of the car park and need to be estimated.

Where costs are estimated directly, care should be taken to correct for subsidies such as the provision of free land by the government or provision of the car park infrastructure to an operator at a price below its cost. Note this is a separate matter to the price that is charged (or not charged, as may be the case) to users of the car parks because the price may be unrelated to the cost of the resources used to develop and operate the car park. Note that, where there is a charge for parking, the benefit per parking space is the avoided resource cost minus the price charged, not the full avoided resource cost (see T2, Chapter 7).

Avoided car ownership

While car trips avoided are likely to be made by cars of a variety of ages, it is more likely that the car given up is a second or subsequent vehicle, and so will be older than the average age of the total vehicle fleet. Given a typical vehicle life of 15 years, it is recommended that the average age of cars whose ownership is avoided should be taken as 10 years.

Cars lose value more rapidly in early years, and the disposal value for a car two-thirds of the way through a 15-year life is about 15% of the cost of the vehicle when new. Given a new car resource cost of \$23,300 (Austroads 2012, adjusted to mid-2014 prices using ABS Cat. No. 6401.0, series A2326656J), the disposal value of cars that are no longer needed by a driver who shifts to public transport will be an average of about \$3,500.

This benefit should be included in the year the mode shift occurs in. The average benefit per potential car saved is taken to be half of this value (i.e. \$1,750 per car driver who shifts to public transport) to allow for some car ownership not being avoided. Reduced car ownership also avoids fixed charges such as vehicle registration and insurance. However, these are charges for resources such as road supply and crash costs respectively that are considered in other components of the appraisal, and so should be ignored when assessing the direct benefit associated with avoided car ownership.

4.8 Benefits to motorists who remain on the road system

4.8.1 Initial estimation

When car drivers shift to public transport in the Project Case, other motorists who continue to use the road network face less traffic congestion, and thus gain a benefit.²² The size of the benefit is larger if the initiative also reduces the number of buses using the roads, and smaller if the number of buses increases.

Determining the extent of this benefit requires:

- An estimate of the quantity of road traffic (number of cars and the average distance travelled) removed from the road system, remembering that not all people who shift from car to public transport were former car drivers (e.g. a shift by a car passenger to public transport will generally not result in an avoided car trip)
- An estimate of the change in travel speed
- A value of travel time for car occupants to estimate the saving that will accrue to road users.

An estimate of the change in travel speed can be determined using one of four methods:

2. Where the initiative involves a transfer from a single road or a corridor, a simple manual approach can be used²³
3. In cases where the effects are likely to be substantial and dispersed, it may be necessary to use a computerised travel demand model to identify the changes in travel time for remaining road users
4. A computerised travel demand model can be used to test the general effect of withdrawing marginal amounts of road traffic under various circumstances to establish relationships between a given reduction in car-kilometres of travel and savings in travel time for remaining road users, with these values being applied more generally
5. Use information such as that prepared by the Department of Infrastructure, Victoria (2005) that combines the methods 2 and 3 above to indicate a value for congestion relief benefits in terms of cents per vehicle-kilometre of reduced car travel under various traffic conditions.

Account should also be taken of any change in bus traffic on arterial roads in determining average travel speed with and without the initiative. For example, a busway or new or upgraded rail line will remove some

²² The benefits described in this section are a component of what are often termed 'decongestion benefits'. Other decongestion benefits include reduced air pollution and reduced social intrusion. Note that it is assumed that public transport has been improved by some means other than reducing road capacity. A project that assists public transport by withdrawing road capacity such as a bus lane may result in increased congestion for existing road users. The methodology to calculate the disbenefits to motorists who continue to use the road system in this case is the same — the only difference is that the analysis shows a disbenefit rather than a benefit.

²³ For example, Bray and Tisato (1997) and Akcelik (1991). Travel time is indicated in BTCE (1996) as:

$$t_a = t_o [1 + a \{(x-1) + \sqrt{(x-1)^2 + bx}\}]$$

(1) where t_o is average travel time per km, t_o is free speed travel time per km, $x = q/Q$ is the volume/capacity ratio (or degree of saturation), an indicator of congestion level, q is traffic volume (vehicle-km/hr), Q is road capacity (vehicle-km/hr), and a and b are constants. With $T = qt_o(q)$, marginal travel time is given by:

$$t_m = \frac{dT}{dq} = q \frac{dt_o}{dq} + t_o, \text{ where } \frac{dt_o}{dq} = \frac{t_o a}{Q} \left[1 + \frac{(x-1) + b/2}{\sqrt{(x-1)^2 + bx}} \right]$$

(2) Luk and Hepburn (1995) provide a useful approximation for constants a and b based on the speed (v) when $x = 0$ and 1 (denoted v_o and v_1 respectively) i.e.:

$$a = 0.25v_o \text{ and } b = 16[1/v_1 - 1/v_o]^2, \text{ where } v = 1/t_a$$

(3) BTCE (1996: Table III.2) reports values for v_o , v_1 , a and b for Australian cities for various road types. Considerations here are limited to arterial roads for which $v_o = 58$ kph, $v_1 = 38$ kph, $a = 14.5$ and $b = 0.001318$.

buses from the arterial road system and add to the improvement in travel time for traffic remaining on the road system.

4.8.2 Adjustment for induced road traffic

The benefits that result from any reduction in road traffic will be eroded if additional traffic uses the road space made available by the diversion of former car trips to public transport. However, the benefit to road users is not eroded completely by this second-order effect because the people who make the additional car trips gain a benefit from their travel. In the case where the additional traffic occurs because some people shift their time of travel, such as from the shoulder of the peak to the peak or from another road, there are benefits to the people who shift and second-order travel time benefits for the remaining traffic in the period or location from which the traffic diverts.

A fully specified multi-modal urban transport model may be applied to estimate the net benefits of any public transport system initiatives, including any induced traffic effects. In this case, the second-order effect is taken into account through the modelling analysis. However, in most cases, models do not fully allow for induced travel other than that which can occur when trip ends change. In these situations, a road traffic assignment (only) model may be applied with fixed paths²⁴ to provide an initial estimate of the decongestion benefits. For appraisal purposes, the net decongestion benefit should be taken as half this estimate, with the factor of one-half representing an allowance for the second-order traffic generation, redistribution and modal split effects (New Zealand Transport Agency 2013). This assumption should be used as a default guide, and any variation from this guide should be justified. One such variation would be to use an elasticity of car use with regard to the generalised cost of car travel to estimate induced demand on an origin-destination basis and to manually adjust the car trip matrix. Bray and Sayeg (2002) provide a more detailed discussion and appraisal of the effects of induced traffic on the economic benefits of a major public transport scheme.

As indicated earlier with regard to unperceived effects of a change in the quantity of car travel (see Section 4.7.4), the increased cost of road maintenance resulting from generated car use is very small and can generally be ignored. It can be included if proponents can provide robust evidence that it will materially change the results of an appraisal.

4.8.3 Default decongestion parameters

Reduced road traffic will produce benefits for users who travel by road after an initiative has been implemented. Two sources of generalised unit decongestion benefit values are given in the following tables:

- Table 11 shows default values as recommended by the Department of Infrastructure, Victoria. The values cover time and vehicle operating cost changes and allow for any 'induced traffic' effects resulting from reduced car travel demand.
- Table 12 shows default values recommended by the New Zealand Transport Agency for the appraisal of public transport initiatives. The benefits include travel time savings, vehicle operating cost savings, crash cost savings, and environmental benefits. The road traffic reduction benefit values assume that the road corridor has at least one point that operates at less than 80% of capacity during the peak period. These adjusted values range from zero to NZ\$64¢ per change in vehicle-km of travel.

The two sets of estimates are broadly comparable in magnitude, although the New Zealand set recognises that decongestion effects may be zero in many situations.

If such default values are used, choose values within the ranges given and use sensitivity testing to assess the impacts of plausible variations.

²⁴ The traffic assignment paths (or routings) should be determined in the Base Case. The Project Case should then be run through the model, with the modified traffic volumes constrained to the same paths fixed in the Base Case.

In cases where user benefits are calculated internally within a demand model, decongestion effects may already be reflected in model outputs. In such cases, a separate external calculation using the unit values provided below is invalid – to include them would lead to double-counting of decongestion benefits.

Table 11 Default decongestion benefit rates, Victoria

Time period	Congestion level	Benefit (\$/veh-km, mid-2014 prices)
Peak	Heavy	1.18
	Moderate	0.84
	Light	0.22
Off-peak	All	0.22

Source: Department of Infrastructure, Victoria (2005). Adjusted to 2014 prices using CPI.

Table 12 Default decongestion benefit rates, New Zealand

City	Benefit (\$/veh-km removed from road, mid-2014 prices)
Auckland	1.43
Wellington	0.92
Christchurch/Other	0.31

Source: New Zealand Transport Agency (2013:3-47)

Notes: Rates cover travel time and vehicle operating cost savings. Accident and environmental benefits need to be allowed for separately. Values are presented in Australian dollars in mid-2014 prices converted from New Zealand dollars at an exchange rate of NZ\$1.00=A\$0.793 at end-June 2008 and Australian CPI to mid-2014.

4.9 Option values and non-use values

4.9.1 Concepts

The concepts of 'option value' and 'non-use values' are commonly applied in environmental economics, which has a large literature on their measurement and valuation. To date, they have been applied less commonly in the transport sector, although it is recognised they incorporate some additional economic benefits to those 'direct user benefits' assessed in conventional social cost benefit appraisals. They are defined as follows:

- **Option value (OV)** represents the willingness-to-pay for the option of having a service available for possible use at some time in the future if required, even though the option may never be taken up (and is not built into any demand forecasts)
- **Non-use value (NUV)** represents the willingness-to-pay for the continued existence of a good or service the individual does not directly consume themselves, and never intends to consume.

Examples of NUVs in a transport environment include: desire to have the facility available for use by friends or family members; desire to reduce congestion and adverse environmental impacts; and access for particularly disadvantaged groups or future generations.

In considering the application of OV and particularly NUV benefits, there are considerable risks of double-counting with the direct user benefits already incorporated in conventional CBAs:

- For OV, it is necessary to distinguish individuals' WTP to have the option of using the service (use option value) from their WTP to actually use the service (already included in CBA)
- For NUV, the benefit component arising from altruistic motives is additional to the conventional CBA, while other components reflect a double-counting of benefits (e.g. changes in land or property values, for profitability of businesses).

Appendix D provides an extended discussion of the concepts.

4.9.2 Relevance and recommended application

In the field of public transport, OVs and NUVs are likely to be most significant in situations where substantial changes to the available transport services are being contemplated.²⁵ This particularly applies to rural and peri-urban areas, where existing low levels of service may be threatened by closure, or where a new service might be introduced where none currently exists. Most of the limited international research on the topic has related to such situations, and these research studies derived OVs/NUVs that were quite substantial relative to 'direct use values'.

It is recommended that OV/NUV benefits be quantified and included in the economic appraisal of public transport initiatives which would involve substantial changes in the availability of public transport services serving local communities outside the main urban areas. Such changes would typically involve the introduction or withdrawal of a rail or bus service connecting the area to a main urban centre.

4.9.3 Methodology and default benefit values

The assessment of option value (OV) and non-use value (NUV) benefits involves two main components:

- Determination of a **unit benefit value** (per affected household per year) associated with the option/non-use value for having the service in question (relative to not having a service)
- Estimation of the **number of households** in the catchment area of the services, to which the unit benefit values are to be applied.

For the determination of unit benefit values, one of two approaches should be adopted:

- Use of **default values** (refer below) – this should be done for all relevant initiatives
- For more major service initiatives, or other cases where the OV/NUV benefits may be crucial to the decision as to whether to proceed with the initiative (or which option to choose), then a **situation-specific survey** should also be undertaken, to determine relevant unit benefit values and catchment area populations.²⁶

The **default unit benefit values** are set out in Table 13. The following points should be noted:

- Values represent the unit OV/NUV benefits, expressed in 2014 \$pa per household in the catchment area
- The values cover only the 'additionality' component of NUV (i.e. that component not included in conventional user benefit estimates), to avoid double-counting
- The choice between the high, medium and low default values primarily depends on the characteristics of the area concerned and the service under consideration, as outlined in the table

²⁵ The transport evaluation procedures in England and Wales specify that "*option and non-use values should be assessed if the scheme being appraised includes measures that will substantially change the availability of transport services within the study area (e.g. the opening or closing of a rail service, or the introduction or withdrawal of buses serving a particular rural area)*". (DfT 2014a).

²⁶ Reference may be made to Wallis and Wignall (2012) for guidance on appropriate survey methods.

- The values are based primarily on the NZ research evidence from 2011 (adjusted for inflation and PPP currency differences) (Wallis & Wignall 2012). These NZ values were towards the lower end of the range of equivalent values from international studies.

Table 13 Default additional option and non-use values for economic appraisal

Category	Notes on typical area and service characteristics	Typical catchment area (km radius)	Default value (\$pa/household, mid-2014 prices) ⁽¹⁾
High	Good level of service (frequency, reliability, travel time, etc.) Car alternative relatively poor (congestion, difficult road conditions, etc.) Service well-matched to desired origins/destinations (stop locations, etc.)	20–35km	\$117
Medium	Between 'high' and 'low' characteristics ⁽²⁾	10–25km	\$67
Low	Poor level of service (frequency, travel time, need to transfer, etc.) Car alternative relatively good Service poorly matched to desired origins/destination (e.g. rail station away from town centre)	10–15km	\$31

(1) Values converted from 2010 NZ\$ to Australian dollars in mid-2014 prices using an exchange rate of NZ\$1.00=A\$0.813 in mid-2010 and Australian CPI to mid-2014.

(2) It is difficult to be more specific about the typical characteristics of the 'medium' category, beyond saying that they are substantially worse overall than the 'high' characteristics and substantially better overall than the 'low' characteristics.

Source: Wallis & Wignall (2012)

The relevant **catchment area** is essentially determined as that area within which households express significant OV/NUV benefits as a result of the initiative in question. While no precise definition of the appropriate catchment area can be given, the following points should be taken into account in estimating the relevant area (and associated number of households):

- Catchment areas are most appropriately related to distance from the rail station or main bus stop(s) within communities
- While they may superficially be expressed in terms of a radius from this point, in practice they are likely to be irregularly shaped, reflecting natural barriers and the presence of nearby (competing) communities and the services they offer
- In general, the size of the catchment area will be related to the quality of the service offered
- In cases where detailed market research is not undertaken, catchment areas can usually be estimated readily from examination of the local geographic and transport situation supplemented by discussions with a few people or groups with good knowledge of the community in question.

Table 13 indicates some typical catchment area sizes (radii) for each of the high, medium or low benefit categories. However, it needs to be recognised that catchment areas may be considerably larger than this in many sparsely-populated parts of Australia (although noting that the introduction of regular public transport services is rarely going to be contemplated in the most sparsely-populated areas).

As noted above and in appendix D, there has been limited research on OVs/NVUs. As a result, practitioners using the above values in appraisals should be aware of the uncertainty associated with them, and so should be used with caution.

4.10 Wider economic benefits

The identification and valuation of wider economic benefits (WEBs) is addressed in Part T3 of these Guidelines. There are no methodological differences to be applied in the case of public transport projects other than the potential to use data that is more specific to public transport users. WEBs are likely to be most relevant to public transport projects that carry large numbers of workers to major employment centres. Care is required to avoid double-counting of WEBs in general with any valuation of the benefits of increased employment of socially disadvantaged people (see Section 4.11).

4.11 Transport disadvantage and equity

Three aspects are considered in this section: the benefit of improved access to employment; the benefit of reduced social exclusion; and the distribution of the benefits of initiatives across the community.

There is an increasing body of knowledge that identifies additional social benefits associated with public transport that arise from the improved access it offers to people who are otherwise transport disadvantaged. There are two components to these benefits:

- Improved public transport allows more people, especially younger people, women, those who do not have a car available to them and those with lower skills, to access employment (Johnson et al. 2014 and Currie et al. 2007). This has positive social and economic outcomes for the people who can now undertake more travel, that are distinct from a perceived benefit of improved social equity.
- Improved public transport reduces social exclusion by allowing those with limited access to private transport to more fully participate in social activities, thus improving their well-being and avoiding costs that would otherwise be incurred from matters such as poor health, other welfare payments and potential crime (Currie et al. 2007).

Both these areas are still in the early stages of consideration. Accordingly, there is limited Australian data to support their valuation and inclusion in economic appraisals and they have not been subject to the extent of peer review and trialling that would ensure broad acceptance by the professional community and users of appraisals. In the UK, Johnson et al. (2014) estimated that the employment effect (as measured by the gross value added per job and the marginal tax wedge) of a change in bus service levels produces a wider economy impact that is equal to 9% to 10% of the value of direct transport impacts. This is a significant effect. However, it needs to be recognised that this benefit overlaps with the calculation of other wider economic benefits - WEBs (see Section 4.9). For example, WEBs take account of improved employment in a general manner, with some of this likely to reflect greater participation in the workforce by people who would otherwise have been disadvantaged by more limited transport options.

With regard to use in Australia, analysts could estimate the employment benefits of a public transport initiative when the initiative is expected to have a significant effect on employment and when wider economic benefits in general are not separately estimated. In such instances, the appraisal may not fully reflect all the wider economic benefits of the initiative but will enable identification of some potentially important benefits. Analysts could estimate these using the methodology set out in Johnson et al. (2014) and the guidelines for the estimation of wider economic benefits set out in T3 of these Guidelines. As indicated there, such benefits should be included in sensitivity tests rather than be incorporated in the core benefits of an initiative.

There has been little analysis of the benefits of improved mobility for those who would otherwise be at risk of social exclusion. Two approaches have been used in Australia in the past. The first sought to identify the benefits of measures proposed to implement the intentions of the Disability Discrimination Act (Attorney-General's Department 1999). The approach adopted was to estimate cross-sector benefits, which were off-setting public sector financial savings in areas other than transport, such as reduced expenditure on the provision of community medical and social services and financial benefits from increased participation of disabled people in employment. The work drew on estimates for the United Kingdom in Fowkes et al. (1994), with the values adjusted for relative populations and exchange rates.

In a second approach, Stanley & Hensher (2011) drew on data for Melbourne to estimate the average value to people of an additional trip to be \$18.40 (in 2008 values) for those in households with average household income. The value of trips was higher for those on lower incomes, probably because of the importance of core trips. They note these values do not include the value of wider social benefits that can be expected to result from reduced social exclusion, such as improved health, increased employment participation, a reduced crime rate and lower welfare benefit payments. A second method to estimate the value of social exclusion considered the influence of social capital, sense of community, household income and trip rate, and resulted in an estimate of the value of an additional trip of \$22.40 (in 2008 values).

There has also been little research, verification and trialling of means to establish the value of reduced social exclusion in other countries. There is no evident research to establish the extent to which such values are incremental to other user benefits. Accordingly, analysts should not include such benefits in formal CBA, but qualitative assessments could be included as part of broader commentary on the results of an appraisal where the effects could be significant. Note that benefits of reduced social exclusion are not mode-specific (Stanley et al. 2011). The concept applies equally to additional trips by public transport, car and active travel. Research should be encouraged to replicate the results of the Melbourne analysis and in other cities and to test alternative means for valuing the effect.

The distributional effects of an initiative are also clearly important in the appraisal of an initiative. It is likely that not all members of the affected community will benefit equally, and it is possible that some may be worse off, even in cases where the initiative would deliver net benefits. Analysts should examine the impacts of initiatives and identify any serious imbalances in the distribution of benefits. They should identify various groups in the community and the impacts on each of them. There are no matters that are specific to public transport in this respect other than that vulnerable groups are more likely to be found amongst public transport users. Additional guidance on investigating distributional impacts can be found in Part T6 of these Guidelines, and in DfT (2014b).

While attempts have been made to include distributional impacts within a CBA framework in the past (e.g. by weighting benefits to various social groups, for example, see Squire and van der Tak 1975, and Harberger 1978), the matter has not gained widespread interest in recent decades and there is no current accepted practice for how it might be applied (see Chapter 12 in Part T2 for a related discussion).

As indicated above, there is not a sufficiently researched body of evidence to support the inclusion of benefits from reduced transport disadvantage as a monetised benefit in economic appraisals. That does not, however, diminish the importance of such effects in the appraisal. Where the effect is likely to be significant in an initiative, it should be listed as a non-monetised impact and described as well as possible in qualitative and quantitative terms. These impacts should be reported in the Appraisal Summary Table (AST) (see Part F3) and highlighted in the business case.

4.12 Summary of benefits

Groups in the community that could be affected by a public transport initiative are described in Table 14 together with a summary of means for calculating the benefits. The benefits of reduced transport disadvantage are not considered further because, as indicated in Section 4.10, there is currently an insufficiently researched body of evidence to support its inclusion as quantified benefits in appraisals. It can, however, be addressed in qualitative terms drawing on the discussion set out in that section.

Table 14: Summary of potential benefits of initiatives to travelers and associated environmental externalities

Beneficiary	Description	Benefit	Data needs and issues
1 Benefits to those who use public transport with the initiative – changes in consumer surplus			
a Existing public transport users	Trips made on the same public transport service before, and with, the initiative	Change in perceived cost of travel (i.e. change in consumer surplus)	The number of trips and the perceived cost of travel in the Base Case and the Project Case. Will generally be based on data in a transport model using either of the methods described in Section 4.2.
b Diverted public transport users	Trips previously made on another public transport service (i.e. route or time) that shift to the improved service with the initiative	The benefit can be estimated directly from changes in the perceived cost of travel, or manually estimated using the 'rule-of-a-half' (i.e. the benefit for a diverted public transport trip is half the unit benefit gained by existing public transport users)	As indicated above. Can also calculate it manually using the number of trips that are diverted between public transport services between the Base Case and the Project Case and half of the unit benefit gained by existing public transport users. See also Section 4.2.
c Former car passengers	Car passengers who transfer to public transport. Also applies to former motorcycle passengers who shift to public transport	As above	As above. If the quantity of car use changes (e.g. a car driver can use a shorter route because they do not need to meet the needs of the passenger), also add the resource cost of the avoided car use. See section 4.7.3.
d Former car drivers	Car drivers who transfer to public transport. Also applies to former motorcycle drivers who shift to public transport	As above for the calculation of the change in consumer surplus In addition, car drivers will have made their travel choice on the basis of the perceived cost of car use as indicated in a transport model (or otherwise can be assumed to include only explicit parking charges and fuel cost). Hence, need to include a resource correction to allow for the difference between the perceived and resource cost of car use. Finally, a shift of car drivers to public transport may enable some car ownership and car parking to be avoided.	Changes in consumer surplus for the former car drivers can be calculated as above. For the resource correction, need the avoided car-km and the difference between the unit resource and perceived car operating costs. The resource costs of car use should include crash and environmental costs in addition to vehicle capital and operating related costs. See also Section 4.3 for a more general description of the benefits. For avoided car ownership and parking, need to estimate the extent to which diversion to public transport enables these savings to occur (see Section 4.7.5 for further discussion). Environmental benefits from reduced car use could be recorded under item 3(a) below if preferred.

Beneficiary	Description	Benefit	Data needs and issues
e Former bicycle users	Cyclists who transfer to public transport	Same structure as for former car drivers	The extent of transfer to/from bicycles is generally small and the associated benefit will generally not need to be calculated. If it should be needed, the resource correction will include unperceived bicycle operating costs and reduced health outcomes due to less physical activity. See also Section 4.7.2 for a more general description of the benefits
f Former pedestrians	Former pedestrians who transfer to public transport	Same structure as for former car drivers	As for former bicycle users.
g Other generated public transport users	Trips on public transport, with the initiative, that were not previously made at all by any mode	Same as for diverted public transport users	As for diverted public transport users. See also Section 4.2 for a more general description of the benefits.
h All existing and diverted public transport users	Improved travel time reliability	Reduced variability of travel time will avoid the need to allow for excess door-to-door travel time to ensure travellers arrive on time.	The mode-specific factor for public transport will implicitly reflect typical reliability for each mode. Improvements to a given mode relative to the average for the mode represent an additional benefit.
2 Benefits to those who continue to use private road vehicles with the initiative – changes in consumer surplus			
a Remaining road users	Road users present in both the Base Case and Project Case benefit from the transfer of some other car drivers to public transport (and transfer of car passengers if this reduces car use) because this leads to less congestion and hence faster and smoother travel.	Benefits includes: • Reduced travel time • Reduced vehicle operating costs (VOCs) • Benefit to any road traffic generated as a result of the improved traffic conditions offset by an associated increase in crash and environmental costs from the additional vehicle-km of travel and a reduction in benefits to other existing road users due to the rise in congestion	As for former car drivers who divert to public transport. May be calculated manually (see Sections 4.3). Environmental benefits from reduced car use could be recorded under item 3(a) below if preferred.

Beneficiary	Description	Benefit	Data needs and issues
3 Other benefits – Changes in third party effects			
a Community at large	Change in environmental impacts	Benefit from: - Reduced car use from shift of car drivers to public transport – see also 1(d) - Reduced environmental impact due to faster and smoother travel for remaining road users as a result of reduced congestion offset by the effect of any generation of road traffic – see also 2(a). Disbenefit from increase in the quantity of public transport services offered.	Part PV5 indicates values for environmental impacts of road vehicle and public transport operation. Austroroads guidelines also include upstream/downstream costs (e.g. embedded energy in cars, etc.), which will be important where there is reduced car ownership. Section 4.6 considers effects related to an increase in the quantity of public transport service that is provided
b Wider economic benefits	Effects on the economy beyond those gained by the categories of beneficiary described above.	Value of flow-on effects of an initiative on the economy	See Section 4.10
c Option and non-use benefits	Value of having the option of using a public transport service for trips that are not yet anticipated, or are currently undertaken by other modes.	Benefit perceived by non-users of public transport. Excludes the expected value (consumer surplus) of any actual future use.	See Section 4.9
4 Increase in revenue to service provider – changes in producer surplus			
a Service provider	Increase in revenue	Increase in revenue from increased public transport trips. This, less the increase in operating costs, produces an increase in producer surplus	The average fare level and the increase in number of public transport trips due to the initiative

5. User benefit parameter values

Chapter 4 provided an overview of the wide range of benefits that can arise from public transport initiatives. Typically, the benefits experienced by public transport users—*user benefits*—comprise the largest single benefit category in the economic appraisal of public transport initiatives. As indicated in Section 4.2, generalised cost of travel is the central focus in calculating the user benefits. The user benefit of the initiative is determined by the change in generalised cost between the Base Case and the Project Case. This chapter provides unit parameter values to be applied to estimate those changes in generalised costs.

The generalised costs methodology expresses all changes in travel time, comfort and convenience in terms first of 'generalised time', which is then multiplied by a 'standard' value of public transport in-vehicle time (IVT) to convert to a generalised cost. The valuation of changes in attributes in terms of generalised time is based on market research evidence as to how public transport users value the various comfort and convenience attributes of services.

The valuations given in this chapter for unit changes in the various attributes are based on extensive market research undertaken in Australia in recent years (involving some 30 studies, mostly in NSW): the great majority of these research studies have used 'stated preference' methodologies. The research findings have been checked for consistency with comparable evidence on user valuations from international studies, and generally show a high degree of consistency.

It should be noted that the 'money valuations' presented in this chapter are expressed in market prices (i.e. as perceived by public transport users through trade-offs with fares paid). They therefore include the Goods and Services Tax (GST) which has been levied on public transport fares in Australia since 2000.

The values provided here are recommended for use across all Australian jurisdictions. Where a jurisdiction has estimates based on its own surveys, results from their use should be reported as sensitivity tests.

The following sections of this chapter address:

- Section 5.1 – 'standard' value of public transport in-vehicle time
- Section 5.2 – values (travel time multipliers) for 'travel convenience' factors
- Section 5.3 – values for vehicle quality factors
- Section 5.4 – values for stop/station quality factors
- Section 5.5 – values for mode specific factors.

The chapter is underpinned by the ATAP Technical Report, *Public transport parameter values: Technical report supporting M1* that can be found in the ATAP Technical Support Library. It provides further information about individual research studies undertaken in Australia and their results, and about the basis of derivation from this research of the values given in this chapter.

5.1 Value of public transport in-vehicle time

The value of in-vehicle time (IVT) is an important parameter in forecasting demand and in project appraisal, enabling travel times to be converted into dollars so as to compare travel time savings with project costs.²⁷ The value of IVT also provides a base on which other travel time components such as access walk time can be valued by applying 'IVT multipliers' (see Section 5.2). In this context, the value of IVT presented in this

²⁷ Other components such as access time, can also be converted in dollars after they have been expressed in equivalent in-vehicle time minutes.

section, unless otherwise stated, is for seated onboard seated time on a bus, train or ferry in the average quality vehicle as perceived by users.

It is important to note the value of IVT plays two distinct 'roles' in transport assessment: a) in demand forecasting, and b) in the estimation of benefits of initiatives:

- For *demand forecasting*, behavioural values representing willingness-to-pay (WTP) values should be used. WTP values tend to vary between modes and travellers with different income levels. The values reported in this chapter are behavioural values.
- For the *appraisal of initiatives*, common practice in Australia and around the world (UK Government 2017, NZ Transport Agency 2017, DAE 2016) has been to use 'equity' values of time, where the same IVT value is used across all modes and individuals with the aim of according equitable treatment to people with different WTP values arising from differences in income levels.²⁸ The values of time provided in Part PV2 for car travel should be used as equity values and applied for appraisals of initiatives across all modes. On completion of the current ATAP WTP investigation, further consideration will be given to a suitable equity value based on a weighted average of car and public transport behavioural values will be considered.

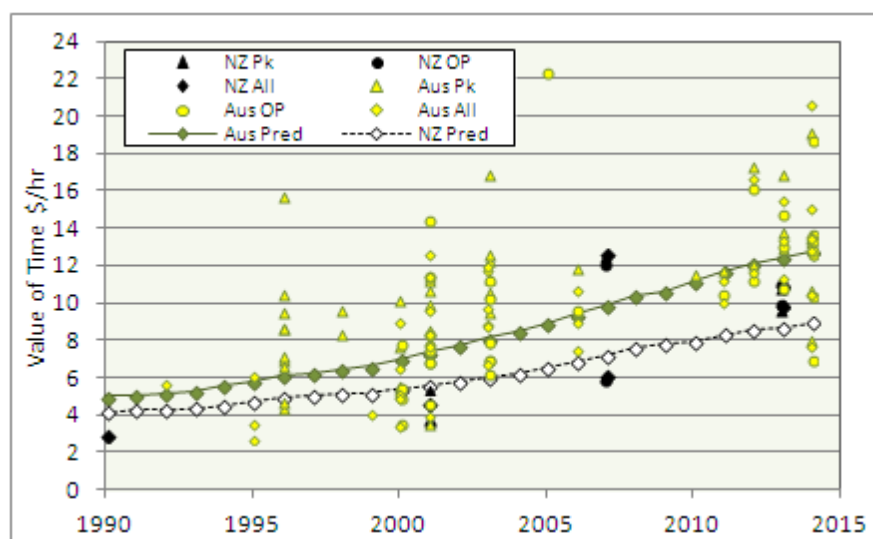
Note that in an economic appraisal, the calculation of generalised costs requires the use of both the equity value of IVT and the IVT multipliers (see Section 5.2). In other words, using an equity value of IVT rather than a behavioural value does not negate the need to use IVT multipliers.

The estimates provided here were derived from a regression analysis of 31 Australian and NZ studies, mainly Stated Preference surveys, undertaken between 1990 and 2014. Most of the studies (27) were undertaken in Australia (of which 21 were NSW studies) with four New Zealand studies. Altogether the studies provided 132 observations. In most instances, public transport users were surveyed but a few studies did survey car users about their preferences for travelling by public transport. Analysis did not discern any consistent difference in the valuations of car and public transport users. Figure 2 plots the observations and shows how the value of time has trended upwards over the 24-year period.²⁹

²⁸ Average income for travellers varies with mode. The primary example is that public transport users have on average lower incomes than car users. This leads to behavioural values of IVT being lower for public transport than for cars. As a result, using behavioural values of time in an appraisal would create a bias against lower income people using public transport relative to higher income people using cars. To avoid this, the same common value of IVT or 'equity value' is used across modes and individuals for transport appraisal purposes.

²⁹ Reporting of the values of in-vehicle time in this section is based on the values from the Australian studies only. In all following sections (5.2 – 5.5) of this chapter, the overall averages of all (including NZ) studies have been used, on the basis that there is no evidence that travel convenience multipliers etc differ between the two countries.

Figure 2: Value of time over time \$/hour – values in local currency in current prices (including GST)



The overall value of in-vehicle time for public transport users in Australia is \$12.80/hour in 2014 prices. This value is expressed in 2014 market prices (including 10% GST).

The value for peak travel is approximately 20% higher than for off-peak travel: the peak VoT for Australia was \$13.90/hour compared with \$11.70/hour in the off-peak.

Values of time also vary by mode as shown in Table 15: the Australian average VoT was \$14.40/hour for rail, \$13.10/hour for tram/LRT, \$11.10/hour for bus and \$18.70/hour for ferry.³⁰

Table 15: Values of public transport in-vehicle time by mode – values in Aus \$ 2014 prices (including GST)

Time period	Rail	Tram	Bus	Ferry	All
Peak	15.60	14.20	12.00	20.30	13.90
Off-peak	13.10	11.90	10.10	17.00	11.70
Overall	14.40	13.10	11.10	18.70	12.80

Table 16 presents guideline factors to estimate VoT by trip purpose for public transport travel. The values have been expressed in proportion to the average VoT (i.e. Table 15). For commuting to/from work, the value of time is 115% of the average, which for Australia would be \$14.70/hour (\$12.80 x 1.15)

Trips to/from school, college and university valued travel time at 74% of the average. Company business trips had the highest VoT at 163% of the average but accounted for only 2% of urban public transport trips.

³⁰ More recent market research in Sydney (for TfNSW) has indicated that the average ferry values are close to the urban rail values given here rather than the higher figures shown. The values obtained for Sydney in the TfNSW research are given in Transport for NSW (2016).

Table 16: Journey purpose values of time and trip shares – ratio of trip purpose VoT to average VoT

Statistic	To/From Work	Education	Personal Business	Company Business	Shopping	Visiting Friends/Relatives	Entertainment/Holiday	Other	All
VOT/Av Ratio	115%	74%	95%	163%	93%	83%	89%	88%	100%
Trip Share	47%	17%	9%	2%	7%	8%	8%	2%	100%

Based on studies 22, 37, 38, 39 & 40.

5.2 Travel time multipliers for ‘travel convenience’ factors

A set of travel time (IVT) multipliers was derived from a review of 40 Australian and New Zealand studies that covered walk access/egress, service interval (service frequency), travel time displacement (not travelling at the most desirable time), interchange (transfer penalties and connection time), onboard crowding and reliability.

To calculate a generalised time measure, the weighted components can be added as shown in the following equation. All the components are included, although in practical applications some may be omitted if they do not change.

$$GT = m_{ae}AE + m_{si}SI + (m_{tp}TP + m_{tct}TW) + IVT + m_{cwd}IVTCWD + m_{rel}REL + \frac{60}{VOT}FARE$$

where:

GT = generalized time in minutes;

AE = access/egress ‘out of vehicle’ walk time;

SI = service interval (mins between departures);

TP = transfer penalty (number by type);

TW = transfer connection walk and wait time;

IVT = in-vehicle time (mins);

$IVTCWD$ = in-vehicle time in crowded conditions (multiplier should be ‘net’ i.e. minus 1)

REL = reliability measure

$FARE$ = fare in dollars

VOT = value of in-vehicle time (\$/hr) in uncrowded seated conditions

m_x = respective multiplier to convert into equivalent IVT minutes.

The generalised time measure can be converted into generalised cost by multiplying by the value of time given in Table 15 or Table 16.³¹ Table 17 presents the guideline travel time multipliers, which are expressed relative to seated time in uncrowded conditions on a vehicle of average quality.

³¹ As the generalised time measure is in minutes and the value of time is an hourly figure, to convert to dollars the GT measure is divided by 60 and then multiplied by the value of time (\$/hour).

Table 17 also includes a column showing multiplier values estimated from a recent OECD study.³² It is seen that the OECD average values and the averages of the Australian study values are generally closely comparable.

Table 17: Summary of travel time multipliers

Attribute	Australian/NZ Review						OECD Review	Notes
Service Interval	0.70						0.5 - 0.8	The SI/IVT value of 0.7 allowed for a upward trend in valuation over the review period and compares with an average of 0.64 based on 115 obs. A curvilinear function was estimated which declined from 0.93 for a 5 min service to 0.65 for a 20 min service to 0.37 for an hourly service.
SI (mins/depts)	5	10	20	30	40	60	na	
SI/IVT Valuation	0.93	0.83	0.65	0.52	0.44	0.37		
Travel Time Displacement	Early		Late		Average		Average	The cost of not being able to travel at the desired time. There were only two Sydney studies giving early displacement at 0.5, late displacement at 0.75 and Av Disp at 0.6. These recommended values are lower based on analysis of SI function and the OECD review.
	0.33		0.50		0.42		0.4 - 0.6	
Wait Time	1.40						1.75 - 2	Valuation based on decomposition of SI valuation.
Net Transfer Penalty (mins of IVT)	Same Mode Transfer		Different Mode Transfer				Penalty	21 studies provided 75 observations from which the average net transfer penalty (excluding time spent at the transfer) averaged 6 minutes for a same mode transfer e.g. bus to bus or train to train. For transfers involving a change of mode e.g. bus to train, the net transfer penalty averaged 10 minutes. For rail, two Sydney studies estimated a cross-platform penalty to be 2 minutes less than a change in platform.
	6		10				5 - 15 (Gross included transfer time)	
Transfer Connection Time	1.50							Time at the transfer (largely waiting time) was valued at 1.5 x IVT based on 25 observations. Valuation likely to vary with walk/wait & conditions (seating/shelter & crowding).
Crowding Multipliers	Crowded Seat	Standing		Crush Standing			Standing	14 studies (30 obs) estimated crowding multipliers. Crowded seating time was valued a fifth higher than uncrowded seating. Standing multiplied the time cost by 1.65 with crush standing more than doubling the cost (2.11).
	1.20	1.65		2.10			1.5 - 2	
Reliability (Average Mean Lateness)	At Stop Departure	On-vehicle Arrival		Average			Lateness	10 studies (15 obs) measured reliability as Average Mean Lateness (AML) calculated as the proportion of services late multiplied by the number of minutes late. Departure AML at stops was valued higher at 5.9xIVT than vehicle or arrival AML at 2.8. The average AML valuation was 4.1.
	5.9	2.8		4.1			3 - 5	
Access/Egress: Walk	1.50						1.75 - 2	21 studies (19 SP, 2 RP) gave av. multiplier of 1.32 however 2 studies of actual behaviour (Sydney Travel Model calibration) gave higher value of 1.5 and this value is recommended. Valuation will increase where greater effort involved (e.g. 4 for up stairs) or in high crowding (2.3).

³² Wardman, M (2014) Valuing convenience in public transport: Roundtable summary and conclusions", International Transport Forum Discussion Paper, No. 2014-02

5.2.1 Changes in public transport reliability

The mode-specific factor reflects a range of perceived characteristics for each public transport mode. Accordingly, the benefit from improved reliability when a passenger shifts from an on-street bus service with poor reliability to an off-street busway or railway will be taken into account in the calculation of consumer surplus. However, it is possible that an initiative could seek to improve the reliability of a mode relative to the typical performance of the mode. This is an additional benefit to users of public transport as it enables them to get to their destination using the same mode without needing to build in buffer time to allow for potential delays in a public transport vehicle arriving at the stop used by a passenger and delays while the passenger is on the vehicle.

It is recommended the approach set out by NZTA (2013:5-486) be used, wherein the benefit is equal to the product of:

- The number of public transport passengers affected
- The reduction in the average number of minutes late for a public transport service expected to occur with the initiative
- The value of in-vehicle travel time
- A factor (equivalent time to a minute late ratio) that is a weighting that reflects the perceived bother to travellers of poor reliability (see Table 18).

The NZ guidelines require that the benefit from improved reliability should not exceed the benefit from travel time savings. However, this requirement is not supported in the ATAP guidelines. Each case should be assessed on its merits.

Table 18: Equivalent time to a minute late ratios

Segment	Departure ⁽¹⁾	In vehicle travel	Combined ⁽²⁾
All	5.0	2.8	3.9
Train	3.9	2.4	3.1
Bus	6.4	3.2	4.8
Work	5.5	2.8	4.1
Education	3.0	3.8	3.4
Other	5.4	2.0	3.7

(1) Services running greater than 10 minutes late should be treated as 10 minutes late.

(2) Based on a 50:50 split between poor reliability at departure and in-vehicle.

Source: New Zealand Transport Agency (2013: 5-487)

The reliability benefit is equal to $EL \times (VTTS(\$/h)/60) \times AML \times NPT$

Where:

EL = equivalent time to a minute late ratio from Table 12

VTTS = value of travel time savings (\$/person-hour)

AML = reduction in average minutes late (minutes)

NPT = number of passengers affected.

5.3 Value of vehicle quality aspects

The values for vehicle quality relate to the provision (or not) of on-board facilities, such as passenger information displays and air conditioning, and to the level of 'operational' quality such as the vehicle cleanliness and the friendliness and helpfulness of the bus driver.

The values for bus, LRT/tram and rail rely heavily on the results of three large-scale market research studies undertaken in NZ (Auckland, Christchurch and Wellington) in 2012/13, Sydney in 2013 and Melbourne in 2014. The three studies used a passenger rating approach that valued quality on a scale from 'very poor' to 'very good'. The scale was converted to a percentage scale that allowed for the 'willingness to pay' to diminish as quality improved and for individual attribute improvements to be valued consistently with improvement 'packages'.

Table 19 presents the values for improving the rating of an individual attribute from a rating of 40% to 80%, which is considered the practical range of low to high quality. Benefits are presented for a 25-minute bus trip and for a 50-minute rail trip.

The sum of the individual attribute improvements deliberately exceeds the value of the modelled package due to the functional specification of the model. For packages of improvements, the model (details given in the ATAP Technical Report, *Public transport parameter values: Technical report supporting M1*), should be used to ensure consistent valuations. The values in Table 19 exclude 'halo' effects whereby improving one attribute improves the ratings of other attributes and hence the overall rating. Analysis of Sydney passenger ratings has shown that halo effects can be significant, doubling the overall impact of individual attribute improvements.

As an alternative to the ratings approach, Table 20 presents the individual valuations of a selection of vehicle features. Two sets of values are tabulated: the valuation per trip in minutes, and the valuation expressed as a proportion of on-board travel time (which enables the values to be applied to other trip lengths). A commentary on the results is provided in the ATAP Technical Report, *Public transport parameter values: Technical report supporting M1*.

Also presented in the Technical Report are values for ferry attributes, which are based on an older (2001) study of Sydney Ferries.

Table 19: Value of improving vehicle attribute ratings from 40% to 80%

Attribute	Value (mins) by mode & trip length (mins)			
	Bus 25	LRT 25	Rail	
			25	50
Vehicle's Outside Appearance	0.72	0.75	0.88	1.76
Ease of Getting On & Off	0.35	0.37	0.43	0.86
Seat Availability & Comfort	0.57	0.59	0.70	1.40
Space for Personal Belongings	0.19	0.20	0.24	0.47
Smoothness & Quietness of ride	0.51	0.53	0.62	1.25
Heating & Air-conditioning	0.50	0.52	0.61	1.23
Lighting	0.36	0.38	0.44	0.88
Inside Cleanliness & Graffiti	0.57	0.59	0.70	1.39
Onboard Information & announcements	0.38	0.40	0.47	0.94
Bus/Tram Driver, Onboard Staff	0.60	0.62	0.74	1.47
Ability to use computer/internet connectivity	0.09	0.09	0.11	0.21
Environmental Impact (emissions, noise)	0.54	0.56	0.66	1.33
Toilet Availability & Cleanliness * IVT>40mins	na	na	na	0.29
Sum of Individual Attributes *	5.38	5.60	6.60	13.48
Modelled Package	4.33	4.66	5.57	11.30
40%-80% Change in all attributes	4.33	4.66	5.58	11.16

Table 20: Value of vehicle attributes and features⁽¹⁾

Mode	Comparison	Attribute Rating	IVT Valuation		Comment
			mins per trip	Percent of IVT	
Rail	Old v New Train	Overall	4.18	8.0%	Sydney CK sets vs Waratah; V set vs Oscar; WTN Ganz Mavag vs Matangi
	Old v Refurb Train	Overall	2.00	5.4%	Sydney Tangara refurbishment.
	Diesel v Electric	Overall	1.78	5.9%	AUC DMUs vs WTN EMUs
	Diesel v Electric	Environ Rating	0.26	0.9%	AUC DMUs vs WTN EMUs
	Onboard Elect. Info Displays	Onboard Info. & announcements	0.40	0.8%	SYD CK Sets vs Waratah, V set vs OSCAR; MEL Comeng vs Xtra; WTN G.Mav vs Matangi
	Air-Conditioning	Heating and air conditioning	0.35	1.0%	Sydney S vs CK set; WTN Ganz Mavag vs Matangi.
	Security CCTVs	Feeling of Personal Security	0.43	1.2%	Sydney Tangara, C, K & S sets vs Waratah (uses Study #25 Personal Security estimate).
	Onboard Staff	Staff availability & helpfulness	0.70	2.3%	Auckland & Wellington Onboard Staff with ticketing duties (vs guards on train).
	Toilets	Toilet availability & cleanliness	0.43	0.5%	Sydney intercity OSCAR & V sets; WTN Wairarapa Line.
Tram	Old v New Tram	Overall	0.89	4.5%	MEL Z class versus E class
	Onboard Elect. Info Displays	Onboard Info. & announcements	0.12	0.6%	MEL A, B vs C, D, E class tram
	Onboard Staff	Staff availability & helpfulness	0.11	0.6%	MEL driver only trams versus SYD LRT with onboard staff
	Low Floor	Ease of On/Off	0.09	0.5%	MEL Z class vs CDE
Bus	29 year old v New	Overall	3.90	17.0%	NZ: 29 year old vs 1.5 year old bus
	20 year old v New	Overall	1.36	5.9%	NZ: Pred rating for 45 seater for 20 year old v brand new (0 years)
	10 year old v New	Overall	0.62	2.7%	NZ: Pred rating for 45 seater for 10 year old v brand new (0 years)
	Premium Routes	Overall	0.91	4.0%	NZ: Std routes vs AUC Inner/Outer Loop & WTN Airport Flyer
	Premium Routes	Onboard Info. & announcements	0.15	0.7%	NZ: Std routes vs AUC Inner/Outer Loop & WTN Airport Flyer
	Diesel vs Trolley	Overall	0.35	1.5%	NZ: WTN Trolley bus vs Diesel bus
	Diesel vs Euro 5	Overall	0.70	3.0%	NZ: Non Euro 5 Diesel vs Euro 5 Diesel bus
	Pre Euro vs Trolley	Environ Rating	0.11	0.5%	NZ: Pre Euro vs WTN trolley
	Pre Euro vs Euro 5	Environ Rating	0.10	0.4%	NZ Pre Euro vs Euro 5 rated bus
	Midi vs Std Bus	Seat Avail & Comfort	0.08	0.3%	NZ: Midi 20 seat vs Std 45 seat
	Std vs Artic Bus	Seat Avail & Comfort	0.09	0.3%	NZ Std 75 seat vs 45 seat, Syd Std vs Artic

(1) In all cases, the second item in the 'Comparison' column is more highly valued than the first item.

5.4 Value of stop/station quality aspects

A similar ratings approach as for vehicles was used to value bus and tram stop and rail station attributes. Table 21 presents the valuations of improving the rating of individual stop/station attributes from 40% to 80%.³³

As with vehicle quality, the sum of the individual attribute valuations exceeds the overall value for the modelled package. A longer list of attributes was valued for rail stations than for bus/LRT stops. There was also a slight difference between bus and LRT stops due to the inclusion of ticket purchase facilities for LRT stops (which lowered the importance weightings for the other attributes). Again, halo effects are excluded (which could double the impact of individual attribute improvements).

Table 21: Value of improving stop attribute ratings from 40% to 80%

Attribute	Value mins/boarding		
	Bus Stop	Tram/ LRT Stop	Rail Stat
Platform Weather Protection	1.18	1.14	0.79
Platform Seating	1.00	0.97	0.77
Timetable Information & Announcements	1.01	0.99	0.67
Station Lighting	0.57	0.56	0.53
Cleanliness & Graffiti	0.89	0.86	0.90
Ease of Ticket Purchase	na	0.30	0.58
Platform Surface	na	na	0.68
Ease of getting to & from the platform e.g. stairs, lifts, escalators	na	na	0.59
Toilet Availability & Cleanliness	na	na	0.16
Availability & Helpfulness of Staff	na	na	0.23
"Retail" - Ability to buy food, drinks and newspapers etc	na	na	0.18
Car Parking and Car Passenger Pick Up and Set Down Facilities	na	na	0.27
Ease of Transferring to & from Bus	na	na	0.11
Sum of Individual Attributes	4.65	4.82	5.70
Modelled Package	3.79	3.88	5.19
Change in all attributes	3.81	3.90	5.21

The rating data was combined with the availability of bus stop facilities (as perceived by users) to estimate the value of providing a timetable (T), RTI (R), weather protection (W), seating (S) at bus stops, and of a raised boarding/alighting platform and providing ticket purchase facilities at tram stops.

Figure 3 graphs the values of different facility combinations. For example, the benefit from providing RTI at a stop with shelter, seating and a timetable can be determined by subtracting T-SW (2.68) from TRSW (3.23) which is 0.55 minutes. By contrast, if RTI(R) were provided at a stop with no other facilities, the benefit would be 0.79 minutes.

For rail stations, the valuations of providing different facilities were based on a cross-sectional comparison of passenger ratings 'with and without' provision. Unlike bus and trams, facility provision was based on 'actual' data provided by operators and territorial authorities rather than passenger perceptions. Table 22 presents the valuations.

³³ Stop/station facilities will mostly benefit passengers who board at the stop but passengers who alight and who transfer at a stop/station may also derive some benefit. The ATAP Technical Report, *Public transport parameter values: Technical report supporting M1* presents some guideline factors to apply to the attribute valuations to value the benefit for alighting passengers

Figure 3: Value of bus and tram stop facilities in IVT minutes

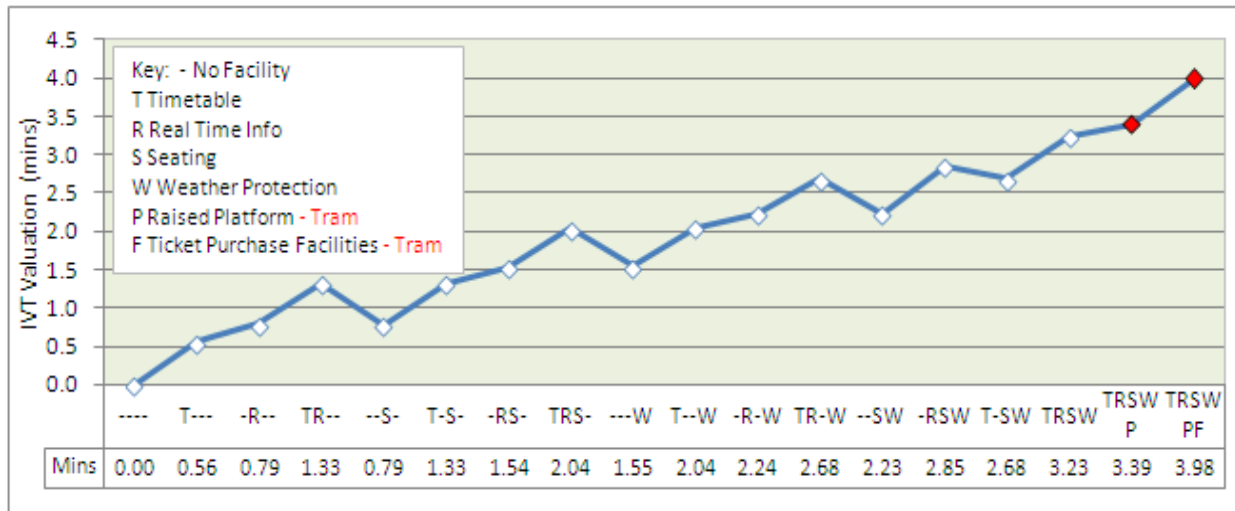


Table 22: Value of rail station facility provision in IVT minutes

Attribute	Value Mins	Comment
Passenger Information Displays (PIDs)	0.28	Mel: Comparison of stations with/without PIDs (adjusted for more facilities at PIDs stations) for suburban trains.
Ticket Purchase Facilities	0.18	NZ: Based on difference in ticket rating at stations with/without ticket purchase facilities.
Staff Presence	0.15	NZ & SYD: Based on staff rating at stations with/without staff.
Retail Facilities	0.13	NZ: Based on retail rating for stations with/without.
Toilets	0.06	NZ & SYD: Based on toilet avail/cleanliness rating for stations with/ without.
Ease of Bus Access	0.03	NZ & SYD: Difference in whether bus transfer available or not
Car Park / Drop Off	0.06	NZ & SYD: Based on car access rating with/without car park.
Bike Racks/Lockers	0.03	SYD: Based on bike rating with/without bike rack/locker (pivoted on Sydney rating model).
Taxi Rank	0.02	SYD: Based on rating of taxi rating (pivoted on Sydney model).
Provision of Lifts/Escalators	0.08	NZ: Based on platform on/off rating with/without lifts/escalators at stations with overbridge.
Provision of Lifts	0.08	SYD: Based on platform on/off rating at stations with/without lifts. The value increased to 0.1 after taking account the increase in use by mobility challenged users. [^]
Flat versus Overbridge	0.05	NZ: Based on plt on/off rating for stats with o'bridge vs flat.
Newly Upgraded/Built	2.33	NZ: Major upgrade/0-5 five years old.
Recently Upgraded/Built	1.32	NZ: Major upgrade/built 5-10 years old.

[^] average station user - Lifts mainly benefit to 'Mobility Challenged' (MC) users (eg wheelchair, infirm, pax with heavy luggage, strollers etc). Taking account trip generation, the benefit was 0.1 mins per trip.

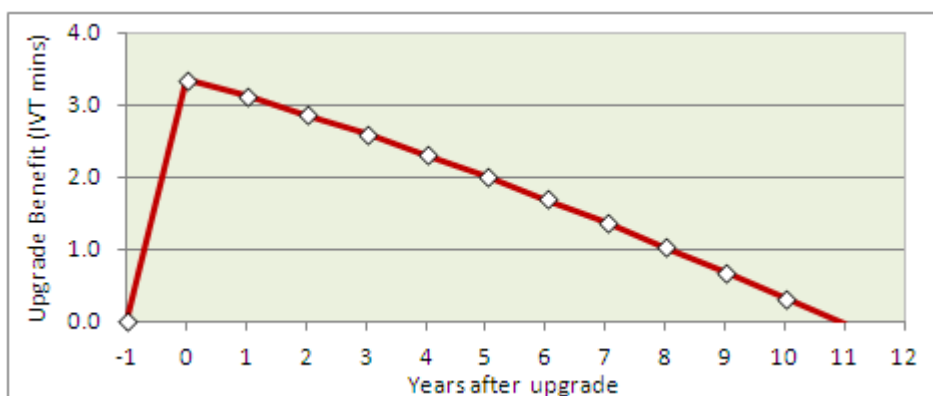
The NZ study was able to estimate the value of minor and major upgrades to stations to passengers by combine the results of two near identical passenger station rating surveys undertaken ten years apart. The value of a major station upgrade, which typically would involve rebuilding the main station building, was worth 3.35 minutes per boarding trip (Table 23). This is the 'brand new' value (i.e. the day after completion). The

value then gradually decreased so that it was worth 2 minutes after 5 years, 0.32 minutes after 10 years and was close to zero after 11 years, as shown Figure 4.

Table 23: Value of minor and major rail station upgrades in IVT minutes

Upgrade	Attribute Rating Affected	Valuation		Comment
		Minor Upgrade	Major Upgrade	
Platform Shelter	Shelter	0.09	0.36	Based on predicted effect on weather protection rating
Seating	Seating	0.16	0.41	
Platform Surface	Platform Surface	0.19	0.44	Major upgrade included rebuilding platforms with access paths to 'street'
" " "	Platform On/off	0.24	0.41	
Information	Information	na	0.30	
Lighting	Lighting	0.11	0.21	
Cleaning/Graffiti	Cleanliness/Graffiti	0.25	0.62	
Toilets	Toilet	na	0.09	
Retail	Retail	na	0.18	Opening of café/small shop on platform or near platform.
" " "	Staff	na	0.04	'Staff' presence from retail facility
" " "	Ticket Purchase	na	0.46	Ability to sell rail tickets from retail outlet.
Car Park	Car Access	na	0.17	Major upgrade of car parking area including resurfacing, lighting, signing and walkways.
Bus Facilities	Bus Access	na	0.03	Improvement of bus waiting area including shelter and signage.
Overall Station	Sum of Attributes	1.04	3.73	Sum of individual valuations
Station Upgrade	Overall Rating	0.94	3.35	Valuation of major upgrade on opening day, on year 5 and on year 10.
After 5 years	" " "	na	2.01	
After 10 years	" " "	na	0.32	

Figure 4: Value of station upgrading by year – value in IVT minutes



5.5 Mode Specific Constants

Mode Specific Constants (MSCs) measure the residual differences in modal quality after differences in travel convenience have been deducted, notably access/egress time, in-vehicle time, service frequency, transfer,

crowding, reliability and fare. They are often used in multi-modal studies for forecasting the patronage for new modes.

Four MSCs were estimated from a review of 15 Australian and NZ studies (31 observations). Table 24 presents the additional perceived cost in IVT minutes of travelling by bus versus the comparison mode as a MSC constant per trip and also as MSC 'time' multiplier (third row), which was derived by dividing by the bus in-vehicle time (second row).

Table 24: Mode Specific Constants in IVT minutes

	Bus - Rail	Bus - LRT	Bus- (Rail/LRT)+	Bus - TW	Bus - Ferry
MSC mins	10	12	7	5	16
Bus IVT mins	33	28	30	40	40
MSC Multiplier	0.31	0.43	0.24	0.12	0.40

+ based on logistic regression

In the third column, a combined Bus versus (Rail/LRT) MSC was estimated based on a regression analysis of the observations taking account the trip length. The predicted MSC for different trip lengths is presented in Table 25.

Table 25: Bus – (LRT/rail) gross Mode Specific Constant by trip length

Bus IVT mins	5	10	15	20	25	30	35	40	45	50	55	60
MSC (mins)	0.6	1.1	1.8	3.0	4.7	7.1	10.0	13.1	16.2	18.8	20.8	22.2
IVT multiplier	0.12	0.11	0.12	0.15	0.19	0.24	0.28	0.33	0.36	0.38	0.38	0.37

A Sydney 2013 study estimated the 'intrinsic' Mode Specific Constant for Rail/LRT versus bus after standardising for quality differences between the modes. For a 25-minute trip, the intrinsic modal preference was worth 2.7-minute advantage for LRT/rail over bus (with negligible difference between rail and LRT). Having established the intrinsic difference, the values from differences in stop/station and vehicle quality can then be added. Table 26 presents the combined values of vehicle and stop quality.

Table 26: Value of vehicle and stop/station quality differences in IVT mins

Attribute	Valuation of Quality Rating (mins) for a 25 minute trip								
	40%	45%	50%	55%	60%	65%	70%	75%	80%
Vehicle	8.0	8.7	9.4	10.0	10.6	11.2	11.8	12.3	12.9
Stop/Station	8.0	8.7	9.2	9.8	10.3	10.9	11.4	11.9	12.4
Total	16.1	17.4	18.6	19.8	20.9	22.1	23.2	24.2	25.3

To illustrate the approach, a proposed LRT system is assessed where the vehicle rating is expected to increase from 70% to 80% and the stop/station rating from 65% to 75%. The vehicle improvement (70% to 80%) would be worth 1.1 minute per trip (12.9–11.8) and the stop/station improvement (65% to 75%) 1.0 minute (11.9–10.9). Thus, the combined quality improvement from the proposed LRT system compared with the existing bus service would be worth 2.1 minutes. The intrinsic MSC of 2.7 minutes is then added to get a gross MSC worth 4.8 minutes.

6. Public transport resource estimation, vehicle costs and operating costs

Changes in the quantity of public transport services that need to be provided may be an initiative in its own right or result from a fixed infrastructure initiative. These changes are due to factors such as changes in services needed to accommodate variations in patronage and travel conditions along existing routes and the introduction of new routes and services. The costs of providing public transport services in the Base Case and Project Case therefore need to be estimated. This can be done in various ways.

At a minimum, costs need to be a function of vehicle-hours and vehicle-km operated and of the number of vehicles required for the operation. The alternative of expressing operating costs solely as a cost per vehicle-kilometre travelled will be inadequate for most urban transport appraisals. This is illustrated with an example where the vehicle-kilometres of service are the same in the Base Case and the Project Case but travel time is reduced because of some improvement in transport infrastructure (e.g. through bus priority measures). The resulting reduction in vehicle-hours needed would reduce fuel consumption, crew costs and perhaps the number of vehicles needed to provide the services.

This chapter sets out a practical and robust approach to estimating the changes in public transport operating costs, covering:

- Estimating the change in public transport operating resources (on a daily and annual basis) that need to be provided in each of the Base Case and the Project Case (Section 6.1).
- Establishing values for unit costs for each of the resources so that the total change in annual costs can be estimated (Section 6.2 for vehicles, Section 6.3 for operating costs).

Some agencies may have their own specific approaches to calculating changes in the operating costs of public transport. These can be used subject to a demonstration that they fully capture the changes in operating costs and are applied consistently. If such methods are used, it is good practice to demonstrate that total operating costs calculated on the basis of unit costs are consistent with the total operating costs for the agency.³⁴

In this chapter, 'operating costs' incorporate all recurrent costs, including annual and periodic maintenance costs. The capital costs of public transport vehicles, including the costs of mid-life refurbishment and the disposal value at the end of the vehicle's economic life, are also addressed in this chapter. These are often also expressed as an annualised average cost, which may be added to the operating costs to give the total annualised costs of an initiative for use where considered useful.

6.1 Estimation of public transport operating resource requirements

6.1.1 Operating resources estimation methodology

Table 27 sets out methods to calculate the annual operating resources associated with the group of services that may be affected by a specific initiative. While the table and methodology have been designed to relate to a bus route, they can readily be adapted for other public transport modes. When the initiative involves changes to a group of services, this method can be applied to all the routes affected between the Base Case and Project Case. The total operating resources for all these routes are summed for each case and the difference (Project Case – Base Case) is then calculated.

³⁴ This check on cost consistency should take account of any agency costs that are truly fixed (in the long-run) or are not related to public transport operations.

These operating resource estimates are then multiplied by relevant unit costs (see below in this chapter) to derive vehicle costs and annual operating costs for the Base Case, the Project Case and the incremental difference between them.

Three measures of operating resources are usually required—bus-kilometres, bus-hours and peak vehicles in the case of buses—as defined in Table 28, which also defines equivalent measures for rail services. In the case of rail (including LRT) services, account needs to be taken of the entire train (e.g. train-hours, train-kilometres) as well as the number of units, or permanently-coupled sets (e.g. unit-hours, unit-kilometres) in the train.

For economic appraisal purposes, vehicle and operating resource estimates must then be established for each year of the appraisal period, for each of the Base Case and Project Case. Four matters are important:

- Generally, it will be appropriate to estimate the quantity of public transport operating resources (using the methods just described, or equivalent) for each of the years for which passenger demand forecasts are prepared
- Account needs to be taken of the schedule for procuring vehicles in the light of any anticipated patronage ramp-up period (this may be particularly significant in the case of major projects)
- Account needs to be taken of the need for additional vehicles (to accommodate forecast patronage growth) over the appraisal period, in each of the Base Case and Project Case
- Account also needs to be taken of the need for additional vehicle purchases required to replace any vehicles expected to reach the end of their life during the appraisal period.

Table 27: Method for estimation of route operating resources (illustrated for bus mode) ⁽¹⁾

Task	Notes re methodology
A. Estimate route (end-to-end) distance and running time	• Route distances are typically derived from the operator database or a map (or vehicle odometer). • Running times may be estimated from existing timetables or other sources. They need to allow for traffic congestion, bus stop time, etc.; they may differ by time period (peak, inter-peak, evening, etc.) and possibly direction. • As a broad estimate, for urban on-street bus operations, typical end-to-end operating speeds are in the order of 25–30 km/hr.
B. Estimate required service headways (frequency)	• In peak periods, the appropriate headways are likely to be determined by the level of demand on the route (peak direction, at the maximum load point): $\text{Services/hour} = (\text{Demand/hour}) / (\text{Capacity/hour})$ • Typical capacity/vehicle estimates for the peak (1-hour) period are given in Table 30. • In non-peak periods, maximum headways are commonly set on 'policy' grounds. • On routes with relatively high demand, non-peak headways may be determined as for the peak period, using the formula above, but generally with capacity/vehicle limited to all-seated loads (i.e. no standees).
C. Derive peak vehicle requirement (PVR)	• $\text{PVR} = \text{Round trip time (RTT)} / \text{headway (rounded up to next integer)}$, and applied to peak period statistics. • $\text{RTT} = \text{Direction A running time} + \text{Direction B running time} + \text{Minimum layover time per round trip}$. • Minimum layover time for a typical bus service is 5–10 minutes per round trip.
D. Derive route operating statistics for typical periods	• Periods used would be typically a weekday peak 1-hour and a weekday inter-peak 1-hour. • Vehicle-kilometres for period: $\text{Round trips/hour} \times \text{Round trip distance} \times \text{Duration of period (hours)}$. • Vehicle-hours for period = $\text{Round trips/hour} \times \text{Round trip time} \times \text{Duration of period (hours)}$. • Peak vehicles – PVR, as above (usually relevant only to peak period).

Task	Notes re methodology
E. Incorporate allowances for 'dead running'	- The above operating statistics relate to on-route running only. These need to be adjusted to allow for 'dead running' to/from the depot or between routes. - At the strategic appraisal level, the following adjustment factors applied to the vehicle-kilometres and vehicle-hours statistics will provide broad estimates (for bus services): - Peak periods 1.20 - Off-peak periods 1.05. - At the detailed appraisal level, vehicle scheduling procedures may be used to derive more accurate adjustment factors.
F. Incorporate allowances for spare vehicles	- In addition to the number of vehicles needed to carry forecast peak period demand (PVR), an allowance needs to be made for additional vehicles for operational purposes (e.g. for unexpected breakdowns and to meet unexpected demand) and for maintenance purposes. - Typical allowances for spare vehicles (all modes) are usually about 10% additional to the peak vehicle requirement – often somewhat above this figure for smaller fleets, somewhat below for larger fleets.
G. Derive annual operating statistics	- For each of the typical peak and off-peak periods for which the above analyses are undertaken, annual estimates of vehicle-kilometres and vehicle-hours may be derived by multiplying: - Typical period statistics (item D) - Dead running factors (item E) - Operations annualisation factors. - The operations annualisation factors represent the ratio of operations statistics (vehicle-kilometres etc.) for a full year to that in the typical period. For example, for peak periods, an appropriate factor from a 1-hour peak period may be 1000 (i.e. 4 peak hours per day, 250 working days per year). - Some additional guidance relevant to estimation of annualisation factors is provided in Section 6.3.3.

- Note:** (1) While this table has been developed to cover bus service requirements, it is similarly applicable to other public transport modes.

Table 28: Operating statistics definitions (bus and train modes) ⁽¹⁾

Item	Definition
Bus-kilometres	- Total distance operated by buses in the period concerned - Includes all non-service running (to/from depot, between routes, miscellaneous, etc.) - May be derived from odometer readings or other sources
Train-kilometres	As for bus, but applies to the distance travelled by a train-set (which will be independent of the number of cars in the train-set)
Unit-kilometres	Train-km multiplied by the average number of units (i.e. carriages) per train-set
Bus-hours	- Total time that buses are out of the depot with a driver in charge - Includes all dead running, short breaks (up to 10 mins) between trips (waiting at termini, etc.), but excludes extended periods with or without a driver (e.g. parked, driver meal period) - May be derived from analysis of vehicle/driver schedules (but in practice often not readily available)
Train-hours	As for bus, but applies to the time the train-set is out of the depot
Unit-hours	Train-hours multiplied by the average number of units per train-set

Item	Definition
Peak vehicles	- Maximum number of buses (or train-sets) required in use at any one time on a normal weekday in order to provide the specified services - May be derived from analysis of vehicle/driver schedules (or, more approximately, by estimation of the peak period ratio of round trip time/headway)

- This table has been developed to cover bus and train operating statistics but is similarly applicable to other public transport modes.

6.1.2 Default annualisation factors for operating resources

As outlined in the previous section, normal practice is to analyse the public transport demand and the operations (for the Base Case and Project Case) for selected time periods only—typically the weekday AM peak period (sometimes also the PM peak period) and the weekday interpeak period. For economic appraisal purposes, those estimates for the selected periods have to be expanded to annual estimates using factors—a process called annualisation.

Section 2.4 discussed the process for demand. For operating statistics, Tables 29 and 30 below provide typical figures for the annualisation process:

- Table 29 provides figures for expansion of vehicle-km and vehicle-hours statistics from any select weekday period to the total weekday. For example, if the selected period used for analysis was 0700-0859 (weekday), the weekday expansion factors would be $100/17.6 = 5.68$ for vehicle km, $100/18.4 = 5.43$ for vehicle hours.
- Table 30 provides figures for expansion from a typical day to annual statistics. For example, the table indicates that the expansion factor from a typical weekday to a year (including allowances for weekends and public holidays) would be $251 \times 100/85.5 = 293.6$.
- Bringing together the results from these two tables, for this example the combined factors from the 2-hour AM peak period to the full year would be $5.68 \times 293.6 = 1,667$ for vehicle km, $5.43 \times 293.6 = 1,594$ for vehicle hours³⁵.

The numbers in the two tables should be regarded as default values (based on several typical metropolitan bus operations). Where reliable local data is available, and particularly for rail operations, it should be used in preference.

Table 29: Distribution of weekday supply of public transport services

Time period	Share of vehicle-kilometres	Share of vehicle-hours
00:00 to 06:59	3.8%	3.4%
07:00 to 08:59	17.6%	18.4%
09:00 to 11:59	21.2%	21.0%
12:00 to 14:59	14.8%	14.7%
15:00 to 15:59	9.2%	9.3%
16:00 to 17:59	17.7%	18.5%
18:00 to 21:59	12.4%	11.6%
22:00 to 23:59	3.4%	3.0%

³⁵ Note that the equivalent annualisation factors for demand (see Section 2.4) would generally be lower than the supply-based figures here, as the demand profile is more 'peaked' (in terms of average boardings per vehicle) than the supply profile.

Time period	Share of vehicle-kilometres	Share of vehicle-hours
Total	100.0%	100.0%

Table 30: Distribution of annual public transport service supply

Time period	Number per annum	Share of annual vehicle-kilometres	Share of annual vehicle-hours
Average working weekday	251	85.5%	85.5%
Saturday	52	8.5%	8.5%
Sunday	52	5.0%	5.0%
Public Holiday	10	1.0%	1.0%
Total	365	100.0%	100.0%

6.2 Public transport vehicle capacities and capital costs

Table 31 lists typical vehicle types used in Australian bus, light rail and heavy (urban) rail systems³⁶ and presents key parameter values related to vehicle capacity and capital cost.

6.2.1 Vehicle types and passenger capacities

Columns A to E of Table 31 provides three measures of passenger capacity per vehicle:

- Number of seats typically provided (col C)
- Nominal capacity (seats plus standees) of individual vehicles (col D) – the number of standees estimated for each vehicle type is generally based on the manufacturer's specification, commonly 4 standees/m² of useable floor area³⁷
- Practical capacity/vehicle for service planning purposes (col E), averaged over the peak 1 hour (peak direction) in Australian conditions – allowing for uneven loadings and variations in demand through the 1-hour period and from day-to-day.

The difference between the second and third measures is important for service planning purposes: for bus and urban rail services, typical standards for service planning purposes in Australasian cities are around 2.5 standees/m² available floor area, while for LRV/trams they are about 2.9 standees/m².³⁸

³⁶ Ferries are not included in Table 30, given the very wide range of ferry capacities and operating conditions experienced in Australian urban passenger transport systems.

³⁷ The standard of 4 standees/m² is substantially below 'crush' capacity, which is broadly double this figure. Standards for buses may be somewhat lower than the 4 standees/m² figure give the difficulty of accommodating high numbers of standees in narrow bus aisles.

³⁸ These standards are based principally on Melbourne practices and experience.

6.2.2 Vehicle capital costs

Default capital costs (exclusive of GST) for new vehicles are shown in column F of Table 31. While these are drawn from a variety of sources, the key sources are WA Public Transport Authority (Transperth) for buses and Public Transport Victoria for light and heavy rail vehicles.³⁹

The key comparison of vehicle costs from Table 31 is as follows:

- For (diesel) buses, capital costs for 'standard' size vehicles (c. 12.0 metres length) are about \$430,000, for articulated vehicles (c. 18.0 metres) about \$650,000 and for double deck vehicles (c. 12.0 metres in length) about \$680,000
- For LRT vehicles (trams), capital costs are around \$5.0 million for 33 metres long double-articulated vehicles (generally similar to Melbourne E-class vehicles)
- For heavy (urban) rail vehicles, capital costs for a typical single-deck 3-car set (similar to MEL or BNE vehicles) are about \$9.0 million.

³⁹ For buses, Transperth has good recent comprehensive bus data relating to one of the largest bus fleets in Australia. For light/heavy rail, Melbourne has the most extensive database nationally on LRT/trams and also has good comparable data for heavy rail.

Table 31: Costs and capacities of public transport vehicles (mid-2014 prices, excluding GST))

	Mode/vehicle type	Length (m)	Passenger Capacity per Vehicle			Capital Cost Per Vehicle (\$'000)	Economic life (years)	Residual Value at Disposal (%)	Rehabilitation ⁽³⁾		Equivalent Annual Capital Cost (\$'000/year) ⁽⁴⁾			
			Seats	Seats+ Practical Standees/ Vehicle ⁽¹⁾	Practical Pk 1-hour Capacity (pk dirn) ⁽²⁾				Time from new (years)	Cost (% of new veh. Cost)	Initial Capital	Rehabilitation	Total	Total Cost / Passenger Capacity ⁽⁵⁾
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
	Bus (Diesel)													
	Mini	8.0	19	19	19	140	10	5	0	0.0%	18.8	0.0	18.8	1.09
	Midi	10.0	30	48	41	340	20	5	12	10.0%	30.6	2.4	33.1	0.89
	Rigid Standard	12.0	43	65	57	430	20	5	12	10.0%	38.8	3.1	41.8	0.81
	Rigid long	14.5	51	78	68	500	20	5	12	10.0%	45.1	3.6	48.7	0.79
	Articulated	18.0	57	90	78	650	20	5	12	10.0%	58.6	4.7	63.3	0.89
	Double decker	12.0	85	100	94	680	20	2.5	12	10.0%	61.7	4.9	66.6	0.78
	Bus (Gas)													
	Rigid Standard	12.0	43	65	57	520	20	2.5	12	11.5%	47.2	4.3	51.5	0.99
	Light Rail													
	Artic ⁽⁶⁾	33.5	64	218	180	5000	35	2.5	20	12.0%	372.7	16.5	389.1	2.38
	Heavy Rail⁽⁷⁾													
	EMU 3-car set	71.0	228	550	470	9000	35	2.5	20	14.0%	670.8	34.6	705.4	1.65
Notes:														
(1)	This is the maximum number of passengers that can be carried per vehicle - allowing for seating capacity and for standing capacity (based on c4.0 standees/m2 net floor area).													
(2)	This represents the practical average capacity/vehicle at the maximum load point, spread over the peak 1-hour peak direction on an average day (based on 2.5 standees/m2 net floor area for Bus and Heavy Rail, 2.9/m2 for Light Rail/Tram).													
(3)	Major rehabilitation/overhaul is assumed to occur once over the life of vehicles.													
(4)	Based on annuity calculations, using a 7%pa (real) discount rate													
(5)	This column allows for costs for spare vehicles, as a 10% addition to peak vehicle requirements.													
(6)	Costs and capacity relate to double-articulated trams (based on MEL E-type vehicles).													
(7)	Costs and capacity relate to single-deck 3-car sets (generally operated as 6-car trains), based on MEL Xtraps2 rollingstock (3-car sets are 71m length, 228 seats, 97 m2 standing area, practical loading standard of 2.5 standees/m2).													
	Cost of capital	0.07												

It should be noted that:

- The above default values should be applied where specific local information is not available. Where local information is available, it is essential that all initial and ongoing vehicle capital-related costs are included as set out in the table.
- The vehicle capital costs shown exclude overhead costs associated with procuring the vehicles, including planning studies, development of specifications, tendering, contracting and supervision costs. These costs can range from 2% to 5% of the costs of the vehicles themselves (as shown in Table 31). For the CBA of an initiative, only costs that are incurred after the decision to proceed with the initiative should be included in the CBA—costs incurred prior to that are sunk and should be ignored in the CBA.

If vehicles are to be leased for a project rather than being purchased outright, their full capital cost should still be included in the economic appraisal in the year in which the vehicles are brought into service, as this represents the year in which the resource is drawn on. It would normally be inappropriate to use lease payment figures because these are related to a financing arrangement that does not directly reflect the use of resources.⁴⁰

6.2.3 Vehicle economic lives, rehabilitation costs and residual values

There is considerable ongoing debate as to the optimum economic lives of urban public transport vehicles (at which point they are disposed of). Factors influencing optimum economic lives include the following:

- Initial vehicle specification and standard of construction (chassis and bodywork)
- Vehicle utilisation (vehicle hours or vehicle km operated per year)
- Any major rehabilitation or overhaul undertaken during the vehicle life (refer below)
- Standard of maintenance
- Continuing availability of spare parts
- Public acceptability and customer appeal
- Obsolescence, resulting from technology developments and cost efficiency improvements (including alternative fuels) for new vehicles, changes in regulations or standards (e.g. environmental emission levels, accessibility standards, seating standards)
- Re-sale opportunities and prices.

For buses, most Australian 'whole of life' studies have concluded that the optimum (economic) life for urban (heavy duty) buses is somewhere from 12 to 25 years, with perhaps a prevailing view of a figure in the 15 to 20 years range. Economic lives tend to be substantially lower for lighter duty buses.

For 'light' rail and heavy rail vehicles, economic lives in the range 30 to 35 years are commonly adopted.

As indicated in column G of Table 31, for economic appraisal purposes (on as consistent as possible basis across modes), we have adopted economic lives of: 20 years for urban (heavy duty) buses; 10 years for light duty mini-buses; 35 years for light and heavy rail vehicles.

However, we note that in practice, vehicles exceeding these ages are often retained, in large part reflecting expenditure constraints on state governments.

⁴⁰ An exception to this would be if the vehicles were leased from a foreign owner: in such a case, the lease costs would be a resource cost to Australia. It is recommended that specialist advice be sought in any such cases.

Given the vehicle economic lives assumed, allowance has been made for a major ('mid-life') rehabilitation during the life of each vehicle (except the mini-buses). As shown in Table 31 (cols I, J), for other buses, rehabilitation costs are estimated at around 10% of new vehicle costs. For rail vehicles, rehabilitation costs are rather higher, typically in the range 12% to 15% of new vehicle costs as some elements of the vehicles such as the control system are likely to be technologically obsolescent by the time of rehabilitation, while other elements such as internal fittings cannot be expected to have lives up to 35 years.

Economic appraisals also require estimates of the residual values of vehicles at the end of their economic lives (/ time of disposal) or the end of the appraisal period where this does not coincide with the end of their economic life. Based on a number of sources, typical values at the end of their economic life are taken as 5% of the replacement value (by a new vehicle) for 20-year old buses, and 2.5% of the replacement value for light and heavy rail vehicles.⁴¹ Table 31, col H).

For estimating vehicle economic values at any other time in their lives (e.g. at the end of the appraisal period where this does not coincide with the end of the vehicle's economic life), we assume that economic depreciation of vehicle values follows a diminishing value (DV) curve (i.e. the value falls by a constant percentage per year of the vehicle's start year value:⁴²

- For buses with a residual value of 5% at the end of a 20-year life, the (real) depreciation rate is 13.9%pa DV
- For light/heavy rail vehicles with a residual value of 2.5% at the end of a 35-year life, the (real) depreciation rate is 10.0%pa DV.

6.2.4 Vehicle annualised capital costs

In addition to showing vehicle costs on a capital (one-off) basis for use in discounted cash flow appraisal, Table 31 also shows these costs on an annualised basis (cols K-M). These can be helpful for: any annualised appraisals; appraisals at more strategic levels or rapid appraisals, such as for a first look at the economics of alternative public transport modes; also as a rapid form of assessment where the appraisal period does not coincide with the life of the assets; and for policy analysis. The annualised costs estimates in Table 31 have been derived from the capital costs on an annuity basis using a 7% (real) discount rate.⁴³

The final column (N) in Table 31 shows the annualised capital cost divided by the practical peak passenger capacity of the vehicles. These figures include an addition of 10% to the costs per vehicle to allow for the additional 10% 'spare' vehicles required. This final column indicates that:

- For buses, typical annualised costs/passenger practical capacity are around \$700 to \$750pa (equivalent to \$2.90 per weekday or \$1.45 per weekday peak period). Unsurprisingly, buses exhibit some economies of scale on this measure, with the mini/midi buses having somewhat higher average costs than 'standard' size buses, and the higher-capacity buses (with the exception of articulated buses) having slightly lower average costs.
- For light rail, typical annualised costs/passenger practical capacity are around \$2,200pa (equivalent to \$8.60 per weekday or \$4.30 per weekday peak period). These cost rates are about three times the typical rates for buses.
- For heavy rail, typical annualised costs/passenger practical capacity are around \$1,500pa (equivalent to around \$6.00 per weekday or \$3.00 per weekday peak period). These cost rates are about twice the typical rates for buses but about 30% below the rate for light rail.

⁴¹ Note that, due to discounting, appraisal results are rarely sensitive to the assumptions on vehicle residual values at the end of the appraisal period.

⁴² Evidence on sale values for second-hand buses indicates that they are generally consistent with a constant %pa DV depreciation basis rather than a straight-line basis.

⁴³ This 7% (real) figure approximates to costs of capital (on a long-term basis) for private sector borrowings on a commercial basis. Public sector long term costs of capital are historically rather lower, at around 5%.

6.3 Public transport operating costs

6.3.1 Estimation methodology

A key component in the economic appraisal of any public transport initiative is the difference in annual public transport operating costs between the Base Case and Project Case. This difference may be expressed as the difference in operating resources between the two cases multiplied by the relevant unit operating costs. These unit operating costs are the focus of this section (the operating resources were addressed in Section 6.1).^{44 45}

A set of default 'typical' unit operating costs (exclusive of GST) applicable to bus, tram/LRT and urban (heavy) rail operations in Australian metropolitan areas is provided in Table 32. For buses, more disaggregated information by bus size is provided in Table 33. The discussion below provides interpretation and further commentary on these unit cost figures. Where local values are available (and are reliable) they should be used in preference.

The operating costs in each of these tables are divided into five categories:

- **On-vehicle crew costs.** These cover all direct costs for on-vehicle staff (drivers, guards, etc.), including wage costs and direct on-costs (payroll tax, superannuation, etc.). They are expressed per vehicle hour (bus) or per set hour (train).
- **Vehicle (direct operating) costs.** These principally cover vehicle fuel and power, vehicle maintenance (labour, parts, outside services) and tyres. They are expressed per vehicle-kilometre or unit-kilometre.
- **Infrastructure operations and maintenance costs.** These cover all costs relating to infrastructure operations and maintenance for track, right-of-way, signalling, power supply and communications systems. For simplicity, and for rapid assessment, these costs are expressed here per track-kilometre (although in practice some of these costs may vary with measures of system usage). For bus services, no costs are included in this category (but refer discussion below regarding road user costs relating to bus operations).
- **Overhead (operating) costs.** This category covers all operating costs not included in the above three categories. These include operations overheads (scheduling, rostering, driver supervision, depot-related costs); vehicle maintenance overheads (e.g. engineering technology services); head office costs (e.g. higher management functions); and general labour and non-labour overheads (e.g. information technology, human resources, insurance). While overhead cost functions may be expressed in various ways, for simplicity and consistency, they are expressed in the tables as a percentage mark-up on all other operating costs.
- **Profit margin.** This 'cost' category represents the amount a commercial operator expects to be paid to compensate for the risks of being in the business. It is additional to all operating costs plus the full economic costs of vehicle ownership (refer Table 31) and represents a legitimate opportunity cost that is appropriate for inclusion in economic appraisals. The profit margin has been expressed as a percentage mark-up on the total operating costs (i.e. the sum of the other four cost categories).⁴⁶ The 'normal' percentage rates in Tables 32 and 34 given are based on considerable evidence from the Australian

⁴⁴ This 5-way cost allocation is clearly a significant simplification of real-world cost structures, in particular, in practice some costs (apart from vehicle capital charges, covered in the previous section) are likely to vary with the fleet size: these would typically include vehicle registration charges, some component of insurance costs and some depot-related overheads. For major initiatives, and particularly for rail-based initiatives, it is recommended that a more detailed cost allocation exercise is undertaken to establish appropriate unit variable costs.

⁴⁵ Typically, in the public transport sector it is assumed that vehicle crew costs are proportional to vehicle hours operated and that most direct vehicle operating costs (fuel, maintenance etc) are proportional to vehicle kilometres operated. While variations in operating speed would typically affect direct vehicle operating costs per km, these effects are generally regarded as of second order and ignored. This is considered an appropriate assumption for the majority of public transport initiatives. The assumption can be relaxed if the analyst can provide robust supporting evidence of cases where speed makes a material difference to the appraisal.

⁴⁶ It is considered appropriate to include a 'normal' economic profit rate of return, including a realistic risk component. 'Super-normal' profits above this should be excluded.

(and international) bus sector (where services have been subject to competitive tendering), and on rather less evidence for the train and tram sectors.

Table 32: Operating cost summary – bus, tram & train (mid-2014 prices, excluding GST)

Cost category	Units	Bus	Tram	Train
On-vehicle crew	\$/train-hour or bus-hour	44	87	320
Direct vehicle operating costs	\$/unit-km or bus-km	1.05	3.00	5.20
Infrastructure operations & maintenance	\$'000 pa/track-km		100	170
Overhead costs	% on other operating costs	25.0	17.5	15.0
Profit margin	% on total operating costs	5.0	4.0	4.0

Notes:

Bus: Standard size of approximately 40 seats

Tram: Typical tram (e.g. average of Melbourne fleet)

Train: Three-car unit typically operating as two units per train (e.g. similar to Melbourne and Brisbane operations)

Table 33: Operating cost summary – diesel buses, by size (mid-2014 prices, excluding GST)

Cost category	Units	Double deck	Articulated	3-axle	Standard (39-49 seats)	Midi (30-38 seats)	Mini
On-vehicle crew	\$/bus-hour	44	44	44	44	44	44
Direct vehicle operating costs	\$/bus-km	1.25	1.29	1.13	1.05	0.88	0.71
Overhead costs	% on other op costs	25.0	25.0	25.0	25.0	25.0	25.0
Profit margin	% on total op costs	5.0	5.0	5.0	5.0	5.0	5.0

Note: Based on diesel-powered buses.

It should be noted that the unit costs in the two tables are intended to be applied in an additive manner (for trains):

$$\text{Total operating cost} = [(\text{train-hours} * \$/\text{train-hour}) + (\text{unit-km} * \$/\text{unit-km}) + (\text{track-km} * \$/\text{track-km})] * (1 + \text{overhead cost \%}) * (1 + \text{profit margin \%}).$$

The total operating costs to provide a service are thus the sum-product of the unit costs and the relevant operating resource requirements (e.g. train-hours, unit-km).

Appendix E provides further details of methodology for estimating public transport operating costs, focusing on the bus mode.

6.3.2 Default unit operating costs

The unit costs given in Table 32 and Table 33 are intended to reflect typical Australian metropolitan/ urban cost rates and would generally be appropriate for the initial economic appraisal of initiatives under consideration. For more detailed appraisal, it would usually be appropriate to make use of city-specific or operation-specific unit cost information, and to compare this against the cost rates given here. We make the following additional comments on this aspect:

- City-specific and operation-specific unit cost information will generally be available for Australian metropolitan (and significant urban) public transport operations, although the cost allocation basis used may differ in some respects from that presented here.
- Where local unit cost estimates do exist, these should be checked against the rates given here. This is particularly important given the relatively long appraisal periods typically applied to major public transport

investments (and noting that for many public transport investments, operating cost differences dominate any capital cost changes): any substantial discrepancies between local unit cost rates and the rates provided here should be investigated further, as the discrepancies may be substantial in the long term.

- In this regard, it is likely to be useful to make reference to benchmarking studies that have been undertaken in Australia (principally for bus and urban rail modes), comparing unit costs between operations in the various metropolitan areas.
- The unit costs given in the two tables for tram/LRT and urban rail modes are representative of recent estimates from principally Melbourne, Sydney and Brisbane for urban rail, Melbourne for tram/LRT.
- For bus services, the unit costs given represent reasonably-efficient costs for operations in the metropolitan areas: they will generally be lower than the cost rates applicable to government-operated (monopoly) bus operations, but somewhat higher than the rates for the more cost-efficient (generally competitively-tendered) private operations.⁴⁷
- The tables do not include any allowance for the costs of road wear caused by buses. To a first approximation, the excise tax paid by bus operators on diesel fuel may be taken as a proxy for these costs.⁴⁸

6.4 Risk and uncertainty

Public transport operations are generally reasonably straightforward and well-understood within the industry — although designing an optimum timetable for train services in a major metropolitan network is far from simple. Four aspects are key to the development of good estimates of vehicle requirements and annual operating costs for the Base Case and Project Case: demand estimates, levels of service, operating parameters and unit costs. We comment on issues relating to each of these aspects, as follows:

- **Demand estimation.** Robust demand estimates are the starting point for service specification and costing. It is important to check the realism of the demand forecasts over the appraisal period (having regard to the dangers of optimism bias – see ATAP Part O2), and also the consistency of demand estimates between the Base Case and Project Case. Demand estimation methods are outlined in detail in Chapter 2.
- **Levels of service.** For peak periods, in most cities/metropolitan areas the levels of service to be provided are generally demand-driven, based on capacity assumptions such as those in Table 21. For all other periods, except on some major routes, typically levels of service are primarily policy-driven (often subject to the proviso that all passengers are able to get a seat). Given that non-peak periods account for the majority of all services (and usually for the majority of total operating costs), it is important to consider off-peak service levels carefully, including for weekday evenings and weekends. The guidance given in Table 28 and Table 29 may be useful in this regard and needs to be applied consistently across the Base Case and Project Case.
- **Operating parameters.** Under this heading, we refer to those parameters required to translate levels of service (frequencies) into operating resources. These cover principally (i) route statistics, mainly terminus-terminus running times and distances; and (ii) dead running (time and distance) requirements. In terms of item (i), the most critical parameter is usually the route running time. This is particularly critical for peak period services, as it determines the peak vehicle requirements – noting that these will be sensitive to road traffic conditions (and their day-to-day variability). In terms of item (ii), it may not be feasible to assess dead running requirements in detail at the initial appraisal stage, but sensible

⁴⁷ Australian experience since the 1990s has been that savings of around 25-30 percent have typically been achieved when services provided by government monopoly providers have been competitively tendered (e.g. Hensher and Wallis 2005, Bray and Wallis 2008, and Wallis and Bray 2013). The last of these references also concludes that savings of around 15 percent have been achieved when services provided by private operators through negotiated contracts have been competitively tendered

⁴⁸ Earlier work (Bray and Wallis 1999 p 258) estimated that the marginal road wear cost of operating buses on urban arterial roads is around \$0.11 per bus-kilometre in mid-2014 prices. As a first approximation, the excise tax paid by bus operators on diesel fuel may be taken as a proxy for these road wear costs. However, there is no comparable tax on CNG fuel. Therefore, where CNG buses are involved, an allowance needs to be added to take account of any change in road wear costs between the Base Case and the Project Case.

estimates are required, consistent between the Base Case and Project Case (refer to guidance in Table 26).

- **Unit costs.** The unit cost rates given in this chapter are based largely on: (i) for buses, reasonably efficient operating costs applying to private operations in Australian metropolitan areas (i.e. lower than public operator costs, but somewhat above the most efficient costs experienced); (ii) for tram/LRT and urban rail, actual operating cost information from Melbourne, Sydney and Brisbane (urban rail) and Melbourne (tram/ LRT). While the figures presented should be sufficient for the initial appraisal stage, for subsequent stages of any substantial initiatives, more detailed investigation of situation-specific unit cost rates should be undertaken. Such investigations should address not only local cost rates at the time, but should also consider likely future cost rates, having regard to cost rates being achieved by other comparable Australian operations and findings from any cost benchmarking studies.

7. Fixed infrastructure capital costs

Capital costs and associated operating and maintenance costs need to be established for each year of the appraisal period for the Base Case and Project Case.

Costs addressed in the previous chapter covered:

- Vehicle (rollingstock) capital costs (including rehabilitation costs, asset lives and residual values)
- Operations (operating and maintenance) recurrent costs, including for:
 - On-vehicle and off-vehicle operations functions
 - Vehicle maintenance costs
 - Fixed infrastructure maintenance cost (e.g. right-of-way/track, power supply, signalling and communications, depots, etc.).

This chapter provides guidance on the capital costs associated with fixed infrastructure for major urban public transport initiatives, including asset lives and residual values.

7.1 General approach to fixed infrastructure cost assessment

There are no special features of public transport that require estimation of capital costs to be undertaken any differently from other transport projects (see new Part O1 Cost Estimation). However, the following matters need to be considered when estimating the capital costs of public transport projects:

- **Uncertainty and risk.** Infrastructure costs of urban public transport initiatives can be very large. This is especially the case with major inner-urban initiatives where development constraints are more severe, and even more so where tunnelling or other structures are involved because of the greater engineering uncertainty associated with such works.
- **Optimism bias.** Experience around the world and over a long period indicates that the costs of major transport projects, including road and public transport initiatives are, on average, substantially under-estimated (Flyvbjerg, Holm & Buhl 2003 and Flyvbjerg 2009). Particular care therefore needs to be taken to identify all possible costs that will be incurred and make appropriate allowance for them. Part O2 further discusses optimism bias in cost estimation. Optimism bias, uncertainty and risk are also discussed in Section 2.5 (for demand estimation) and Section 6.4 (for operating costs).
- **Re-investment.** Public transport initiatives can include items with asset lives that are shorter than the appraisal period. These items need to be identified and allowance made in the economic appraisal for their replacement.
- **Residual value.** Public transport initiatives can involve a range of assets with different asset lives. It is therefore possible that some assets may still have a substantial remaining economic value at the end of the appraisal period, and so estimation of this value can be important.
- **Maintenance.** Some public transport infrastructure can require substantial maintenance because it involves mechanical and/or electrical elements, is exposed to the elements or is subject to wear and tear from public use. Care is needed, drawing on available data, to fully estimate the maintenance costs for such infrastructure, including the extent to which they are fixed (per year) or vary with the use of the system (e.g. per train km).

Fixed infrastructure capital costs are, to a considerable extent, specific to the circumstances of an individual initiative.

7.2 Indicative (default) capital costs

As a very general guide, Table 34 provides broad costings (ranges) for fixed infrastructure for major public transport initiatives in large urban areas (excluding GST). These costs should be used only in a very indicative manner and only for work undertaken prior to the strategic merit test.

7.3 Economic lives and residual values

Different asset elements of public transport infrastructure have different economic lives.

Table 35: Typical economic lives for infrastructure assets

35 provides a set of values of economic lives that are commonly used. Various transport entities may adopt slightly different values.

The economic lives should be the period over which the asset can support the provision of public transport services based on the annual and periodic maintenance allowed for the assets. These lives may sometimes differ from asset lives that are used for accounting purposes, which may be guided by taxation and other factors.

The economic lives are reflected in two ways in economic appraisals:

- Allowance needs to be made for re-investment in assets that reach the end of their economic lives during the appraisal period.
- Where infrastructure assets have an economic life that extends beyond the last year of the appraisal period, any residual value of the assets should be recorded in the assessment. As discussed in Part T2 Section 3.3, the Guidelines recommends that:
 - Residual value be included in the assessment as a benefit in the last year of the appraisal period
 - In calculating residual values, depreciation of fixed infrastructure assets be calculated on a straight-line basis over the asset life.

7.4 Risk and uncertainty

Infrastructure capital cost estimates should be supported by a formal indication of the level of detail of the engineering investigation and design on which they are based and should include allowances to account for the level of uncertainty. Such allowances will be large during the early stages of project preparation and will decline as engineering work progresses. The approach for estimating costs for public transport projects is no different to that for other projects.

As discussed earlier with regard to public transport vehicle requirements and operating costs, the extent of under-estimation of the capital costs of public transport initiatives tends to be greater than for road projects in general, though it is similar to that for fixed links such as major bridges. This may reflect the greater extent of rare or unique features of many public transport projects, hence the need for greater care in estimating the costs for such projects.

A number of specific analytical approaches can be taken to addressing risk and uncertainty, as set out in T2, Chapter 11 of these Guidelines. Dealing with optimism bias is discussed in Part O2 of the Guidelines.

Table 34: Indicative infrastructure costs for major urban public transport initiatives (excluding GST)

Infrastructure type	Indicative cost (\$m, mid-2014 prices)	Comment
Systems infrastructure		
Network control centres	See comment	Network control functions for new public transport initiatives are often incorporated in existing centres. Incremental costs e.g. software upgrades, display units and expansion of facilities, will vary.
Network infrastructure (excluding land)		
Railway track and formation – surface dual track	\$40–80M per route kilometre	Excludes station costs.
Railway track and formation – dual track, twin bore tunnel	\$100–150M per route kilometre	Excludes station costs. Assumes reasonable ground conditions for tunneling. Cost will be higher if ground conditions are poor, or if significant underpinning of existing buildings is required.
Light rail – surface dual track	\$60–100M per route kilometre ⁽³⁾	Includes all D&C plus overhead costs, including stops/stations (but excluding land). Cost at the lower end is for ideal locations, with minimal roadworks and service relocation. Cost at upper end in complex locations e.g. CBD, where roadworks, high quality 'stops' and service relocations will be required.
Dedicated bus lanes - dual track	\$5–20M per route kilometre	Highly variable, depending on degree of separation from other traffic, extent of traffic-resignaling, quality of finishes at bus stops and extent of IT systems such as passenger information.
Nodal infrastructure		
Railway stations - surface	\$15–40M per station	Assumes relatively simple stations on new tracks.
Railway stations - underground	\$30–60M per station	Dependent on scale of station, depth of station, extent of access/egress (including emergencies) requirements.
Light rail stops	\$0.5–2.5M per station	Highly variable, depending on extent and quality of facilities and urban design treatments. Upper end costs more common in established urban areas.
Car park – at grade	\$15,000–\$25,000 per space	Variable, depending on site conditions.
Car park – multi-deck parking	\$30,000–\$40,000 per space	Assumed above ground (below ground significantly higher costs).
Interchanges	\$10M–\$15M per interchange	Highly variable, dependent on size of interchange, features etc. Large interchanges in established areas will cost more than the upper figure.
Wharves	\$2–5M per wharf	Variable, depending on scale of facilities, range of vessels, need to accommodate variable maritime conditions.

Note: (1) All items exclude land costs.

(2) Information provided by TfNSW and other sources.

(3) These costs largely based on analysis of costs for Australian LRT schemes (open, under construction and planned) since 2010.

Table 35: Typical economic lives for infrastructure assets

Infrastructure type	Typical economic life – years	Source ^(a)
Network infrastructure		
Rail extensions, busways	70	Based on IPART
Earthworks	50–150	Based on RailCorp
Bridges – concrete	120	NSW P&G
Bridges – timber	40	NGTSM
Tunnels	100	NSW P&G
Culverts	100–120	NSW P&G
Rail track	50–100	Based on RailCorp, IPART
Turnouts	15–50	RailCorp
Ballast	60	RailCorp
Sleepers – concrete	50	NSW P&G
Sleepers – timber	20	NSW P&G
Road pavements - concrete	60–80	Based on Austroads
Road pavements – asphalt	30–40	Based on Austroads
Bus priority schemes	20	IPART
Nodal infrastructure		
Stations – rail/light rail	50	NSW P&G, IPART
Bus stops	20	NGTSM
Ferry wharves	40	IPART
Interchanges, commuter parking facilities	50	NGTSM
System and miscellaneous infrastructure		
Depots, buildings (miscellaneous)	40–50	IPART
Plant and equipment (miscellaneous)	12	Based on IPART
Control centres (IT systems, excl. buildings)	5	NSW P&G
Rail signals and communications	20	NSW P&G

(a) Key to sources:

NSW P&G: Transport for NSW (2016). Principles and guidelines for economic appraisal of transport investment and initiatives.

IPART: Independent pricing and regulatory tribunal, NSW (2016). Transport fares determination: Final report, information paper 2 - cost recovery.

RailCorp: RailCorp (NSW) (2016). Annual Report 2015/16, vol 2.

8. Performance measurement and monitoring

8.1 Introduction

This section provides material on performance measures ('key performance indicators', KPIs) and their application specific to the public transport sector, and in particular relevant to the consideration of public transport investment proposals.

It builds on and supplements the more generic material on this topic in other parts of the ATAP Guidelines, principally:

- Part F1: Goals, Objectives and Targets
- Part F7: Post Completion Review
- Part T6: Benefits Management.

8.2 The strategic planning framework – goals, objectives and targets/KPIs

ATAP Part F1 outlines the strategic planning framework adopted in the Guidelines, involving seven main steps. Step 1 is concerned with the specification of goals, objectives, targets and associated performance measures (KPIs). Table 36 sets out the definitions used for each of these.

Table 36: ATAP Framework – terminology

Term	Definition
Goals	Statements that describe the fundamental economic, social and environmental outcomes that a jurisdiction is aiming to achieve through its activities across all sectors (not just transport).
Objectives	Specific statements of outcomes that a jurisdiction is aiming to achieve through its transport system.
Performance indicators and targets	A key performance indicator (KPI) is a measure that enables monitoring of performance in terms of progress towards a specific, defined objective. A target is the desired level of performance for a specific performance indicator. Performance indicators and targets are mechanisms to operationalise objectives.

Source: Paper F1, chapter 2.

8.3 Role and perspectives on performance measures and targets

Performance assessment (relative to targets) is most relevant at two of the steps in the ATAP Framework:

- **Step 2: Problem identification, assessment and priority setting.** At this 'before' stage, current (and projected) performance should be measured, and targets set against each objective. This 'gap' analysis will identify problems and deficiencies and point the way towards options that can address these deficiencies.
- **Step 7: Post-completion review.** At this 'after' stage, the review should measure the 'after' performance against the targets established earlier, address whether the forecast performance improvements have been achieved, and if not, identify what further action might be required to enhance performance.

Targets and KPIs should be set for objectives at all planning levels and be consistent and integrated. Each objective should have at least one associated KPI and specific target.

The comparison of targets with performance indicators provides a gap analysis, which shows the extent to which objectives are being met.

Performance can be measured from several different perspectives, specifically.

- **Process:** measures the type of process, policy or activity
- **Inputs:** measure the resources invested in or used by an activity
- **Outputs:** measure the level and extent of activity
- **Outcomes:** measure the end result.

In formulating KPIs and associated targets, the following characteristics are seen as desirable:

- **Be simple and easy to convey.** The language used to express targets and KPIs should be non-technical and straightforward, capable of being understood easily by the public.
- **Relate directly to the identified objectives.** Targets and KPIs need to be formulated carefully to accurately reflect objectives and facilitate problem identification. It should be possible to trace a clear 'pathway' from a target/KPI to a related objective (and back to the high-level goal).
- **Relate to outcomes, not outputs.** Outcomes are better indicators of the effectiveness of an activity. Outputs usually measure the level of activity and not its end result (economic, social and environmental): they should only be used if no appropriate outcome measure is available.
- **Facilitate benefit measurement.** Formulating targets and KPIs in terms of positive outcomes or improvements enables the assessment of the benefit of a specific initiative against its cost.
- **Be measurable from a practical perspective.** The analytical tools, data and/or resources needed to monitor a target or KPI should be readily available at a reasonable cost. This should not preclude the use of 'soft' measures, such as public and user perceptions. Such measures are often the best means for assessing quality and amenity performance of public transport services from the user perspective.
- **Reflect recognised performance measures.** Targets/KPIs should incorporate measures that are recognised as reliable and appropriate.

Targets and KPIs are often expressed in terms of:

- **Trends over time** (e.g. % reduction in accident rates or travel times over N years); and/or
- **Performance relative to other jurisdictions** (e.g. unit costs of operating bus services in an area relative to a recognised regional benchmark rate).

Many jurisdictions will have guidelines for developing targets and KPIs. The 'SMART' criteria are commonly used to guide practitioners in the development of KPIs:

- **Specific** – well defined and focused
- **Measurable** – can be measured to track progress
- **Achievable** – realistic, practical and stretching
- **Relevant** – directly relate to objectives
- **Time-bound** – clear timeframes set for each indicator.

8.4 Potential KPI Metrics for public transport infrastructure proposals

An extensive literature exists on performance measures ('metrics') for public transport services generally, which addresses requirements from multiple perspectives such as those:

- Relevant to government authorities (in roles of funder, regulator)
- Relevant to operators (requirements generally specified in operator contract, including targets and related financial and other incentives)

- Relevant to users and user organisations (e.g. public transport user associations, groups representing people with accessibility difficulties).

Metrics will also often differ between public transport modes, given their differing natures (e.g. rail vs bus vs ferry services), but consistency is desirable whenever possible.

Typically, many metrics will be defined in a hierarchical structure, relating to the urban public transport system overall at the top level, with this overall data being disaggregated by mode, route, time of day etc. to identify particular 'hot spots'.

No attempt is made here to provide a comprehensive specification of KPI/performance metrics for the ongoing monitoring of public transport system performance generally. Rather, the following focuses on performance metrics likely to be most relevant in the context of the consideration of public transport proposals (generally with an infrastructure focus) for which these Guidelines are most relevant.⁴⁹

Table 37 provides an (illustrative) set of KPIs/performance metrics appropriate to a range of investment objectives and associated benefits commonly relevant to public transport investment proposals.

Table 37: Potential KPIs to support public transport infrastructure funding requirements (illustrative)

Investment objective	Benefit sought	Possible service or outcome KPIs
Service capacity	• Reduced crowding on current public transport infrastructure • Reduced car dependency and increased public transport mode share • Supporting anticipated patronage and population increase	• Passengers/m² in peak • Passenger load factor (% capacity) • % passengers standings 20+ mins from the CBD • VKT and public transport mode share • % household daily trips by car • # annual peak period passenger trips.
Service coverage	• Improved network coverage in growth centres • Improved accessibility to public transport, especially for socio-economic disadvantaged areas	• % houses within 500m of public transport stop • SEIFA index ^(a)
Service quality	• Savings in public transport journey time • Providing safer public transport • Improved on-time running and reliability • Improved accessibility to stations/stops	• Average journey time • Incidents per million service km • % services arriving and departing on time • % vehicles/infrastructure complaint with DSAPT^(b)
Service efficiency	• Improved asset utilisation • Improved reliability of infrastructure • More efficient vehicles having lower GHG emissions	• % peak vehicle utilisation • Service faults per 100,000 km • CO2 emissions per passenger km

⁴⁹ The following material is drawn principally from Infrastructure Australia (2013): 'Urban Transport Strategy' and incorporates consultancy inputs to that report from LEK (2011). 'Aspects of Public Transport'.

- (a) Socio-Economic Index For Areas
- (b) Disability Standards for Accessible Public Transport (national standards).

As noted above, these metrics would generally be assessed at two stages in the strategic planning process (where B refers to the outcome in the Base Case and P to the outcome in the Project Case):

- **Step 2 ('before'):** For a given performance indicator, compare project case forecasts (P_{before}) with base case forecasts (B_{before})
- **Step 7 ('after'):** As part of a post-completion review, assess performance following implementation of the improvement (P_{after}) with a reassessment (if necessary) of the performance that would have been expected if the improvement proposals had not been implemented (B_{after}).

The difference ($P_{\text{after}} - B_{\text{after}}$) would then be a measure of the impact of the proposal on the performance indicator; and this could be compared with the prior forecast of the impact ($P_{\text{before}} - B_{\text{before}}$); any differences and the factors accounting for these would form valuable components of the post-completion review.

Appendix A Market research methods for application in public transport demand forecasting

This section provides commentary on market research and analysis methods that may be used to analyse public transport demand to derive parameters for elasticity-based and related demand forecasting methods discussed in section 2.2⁵⁰.

Market research data for this purpose may be drawn from two main categories:

- **Revealed Preference (RP)**: data on observed behaviour, revealing choices that have actually been made by travellers
- **Stated Preference (SP)**: data based on the stated behaviour of survey respondents when offered a hypothetical set of travel alternatives by the researcher.

A.1 Revealed Preference (RP) data

The four main types of RP data, each with a related method of data analysis, are Time Series Analysis, Cross-sectional Analysis, Panel Data, and Before & After Studies.

Times series analysis

Time series analysis estimates the relationship between a dependent variable (e.g. public transport travel demand) and one or more explanatory (or independent) variables (e.g. price, service levels, fuel prices), using data collected for each variable over a number of time periods.

The simplest (and most common) time series approach assumes the dependent variable will completely adjust to any change in the explanatory variables within the same time period in which the change takes place. More sophisticated analyses use 'lagged' models, in which the dependent variable is expressed as a function of explanatory variables in both the current and previous time periods. These are better able to capture any longer-run effects from changes in the explanatory variables. Temporary or permanent shifts in the dependent variable as a result of a factor outside the model (such as the impact of sporting events on public transport use) need to be accounted for, using dummy variables to ensure such shifts are not incorrectly attributed to the other dependent variables.

While all relevant variables should be included in the analysis, explanatory variables based on aggregate data often move together (e.g. GDP and elapsed time), causing multi-collinearity and the confounding of effects. Because of this, some models are estimated using annual changes in each variable. Although such 'difference' models are less prone to auto-correlation of the independent variables, they bring their own difficulties and are prone to correlation (e.g. reductions in traffic because of random events will be automatically followed by increases as demand returns to 'normal' and vice versa).

Cross-sectional analysis

As with time series analysis, cross-sectional analysis determines the relationship between a variable of interest and a number of explanatory variables, but it uses data from a single point in time obtained from a range of different locations (e.g. public transport use, fare levels and service levels from a series of

⁵⁰

The material in this section draws heavily on Wallis (2004).

different cities). Other cross-sectional models use data on individuals, allowing for different prices, incomes and other controlling factors, to estimate parameters for discrete choice models.

Problems arise with cross-sectional models when spatial and socio-economic differences are not explicitly included in the model or are confounded (e.g. with higher-income people living in outer suburbs and lower-income in inner suburbs or vice versa), and causation is incorrectly attributed to differences in the independent variable set.

Pooled cross-sectional and time series data sets may also be used (where they are available), allowing greater freedom to estimate more complex model structures than is possible with either of the data sets alone.

Panel data

Panel data are cross-sectional disaggregate data collected over a period of time from the same group of users or a group of users with similar characteristics, with the aim of eliminating variations in behaviour that are related to changes in socio-economic factors and personal preferences. This reduces the risk of attributing changes in observed behaviour over time to changes in the transport network, for example, when they are actually related to variations in the socio-economic characteristics of the sampled population. However, the usefulness of panel data to monitor transport behaviour is limited in many countries because of the relatively high residential and employment mobility.

Before and after studies

These methods typically examine demand at a detailed level before and after a service, etc change. This type of study is often used to evaluate a change in demand caused by a one-off significant change in fares or service levels, and the methods can be designed to meet any specific study requirements.

In practice, problems often occur because of the difficulty in accounting for other factors affecting demand between the 'before' and 'after' periods (e.g. weather, economic factors), although these may be at least partially overcome through the use of control groups. Other disadvantages include the possibility of sample bias and the difficulty in properly allowing for any longer-term lagged effects.

A.2 Stated Preference (SP) data

Stated Preference (SP) methods, a form of quantitative market research, have been developed over the last 20-30 years to address the limitations of RP analyses. Because most RP analyses rely on aggregate data (e.g. from ticket sales), one issue is the difficulty of obtaining estimates disaggregated by key factors such as socio-economic characteristics that are not routinely available from operators. Another issue is that RP methods can only derive elasticities for the types of changes made in the past: they cannot generally address issues such as new routes, changes in the quality of future services and the introduction of modes with new characteristics.

SP experiments typically offer each of a group of respondents a number of alternatives involving variations in some of the attributes (e.g. fares, journey time, service frequency) of a journey. Other aspects of service quality remain unchanged and respondents are asked to choose (or 'state') their preference between the alternatives presented. The method of analysis uses similar statistical methods to those used for analysing RP data.

The major weakness of SP estimates is that respondents may or may not behave in practice as they say they will in the experiments, particularly where the range of alternatives offered are well outside the experience of the respondents. This is related to problems of perception. For example, SP can report how passengers claim they will behave if they perceive that service frequency has doubled, but if current perceptions of service frequency differ from objective measures, very different results may ensue when service frequencies actually change. Similar problems arise when new modes are investigated: there is a considerable danger in over-stating the performance of the new mode relative to the known performance of the existing mode. Care must be taken when applying SP elasticity values in isolation: experience has shown

that respondents typically overstate their response to alternative scenarios, and thus SP elasticity values are often significantly higher than the corresponding RP values obtained from observed data. Where possible, outputs from SP experiments should be combined with elasticity values (e.g. for fares) derived from RP data, effectively using the RP values to 'anchor' the SP results.

A.3 Summary of RP and SP methods

While each method of estimation has its practical advantages and disadvantages, experience also shows that the choice of methodology influences the estimate obtained. RP before-and-after studies and time-series analyses tend to produce the lowest values. RP cross-sectional modelling using generalised costs usually produces higher values, while SP studies tend to produce the largest values.

The derivation of elasticity values and related parameters from RP and SP data sources is not a straightforward matter. It is recommended that expert advice be sought on this aspect, particularly in relation to the design and analysis of SP surveys.

Appendix B Methods for estimating changes in consumer surplus

B.1 Method 1 – Simple rule-of-a-half manual method

F=The first method is based on the number of existing trips (i.e. those made in the Base Case and the Project Case) and the average perceived cost of trips in each case. This method can only be accurately used in the simplest of situations such as an improvement to a local public transport service that does not change the number of trips or their origins and destinations. By implication, it cannot be used where a public transport initiative will have significant effects on travel demand, such as when a new public transport service is introduced and leads to generated demand or diversion from private vehicle travel or a change in the origins and destinations of trips.

If only a modest level of generated demand is expected, and no diversion from some other mode of travel, the simple method can still be used. In this case the change in consumer surplus can be calculated in the usual manner, with the change in consumer surplus for generated trips based on the rule-of-a-half—the average benefit for each of the latter trips is equal to half of the benefit gained by existing public transport trips made in the Base Case and Project Case (see Box 4 in Volume T2 of these Guidelines for more information on the rule-of-a-half). In this case, the benefit derived for the generated demand should be very small relative to the benefits accruing to existing users, reflecting the limited quantity of generated demand and the small average benefit accruing to each generated user.

B.2 Method 2 – Rule-of-a-half manual method using multi-modal demand model

Many if not most public transport projects involve more complex changes in travel demand than described in method 1. These can include changes in the quantity and location of travel that is undertaken and the mode of travel that is used. These changes involve network effects and require use of a multi-modal travel demand model to establish likely changes in travel demand.

In the case where the travel demand matrix changes between the Base Case and Project Case in a non-uniform manner (i.e. the quantity of travel between some origins and destinations changes in a different proportion to others), the change in consumer surplus resulting from these changes cannot be precisely determined using aggregate model outputs such as the number of trips and the average cost per trip for the entire network (as in method 1). Rather, the analysis must be undertaken on the basis of the quantity of trips and the change in the perceived cost of travel for each origin (O) – destination (D) zone pair used in the model, drawing on the travel demand matrix and the generalised cost matrix for each mode of travel for each of the Base Case and Project Case. The consumer surplus for existing and generated (or suppressed) trips is estimated for each OD pair for each mode using the data in these matrices, with the consumer surplus for generated (or suppressed) trips estimated using the rule-of-a-half.

As in method 1, the change in consumer surplus is also calculated in the usual manner. The rule-of-a-half will now apply not only to generated trips (as in method 1), but also diverted trips.

Further discussion of this method of benefit calculation can be found in the following areas of the ATAP Guidelines: Part T2, Chapter 6 and Section 7.3; Part T1 Section 3.4.4. The calculations are undertaken for each O-D pair, across all trip types, all modes and all time periods.

Note that the generalised cost of travel (sometimes referred to as the perceived cost of travel) should include factors that reflect the perceived merits of different public transport modes and other aspects of the journey by public transport, such as service quality attributes of each mode such as comfort, convenience and reliability (see Chapter 5 for further information).

Two final points should be noted:

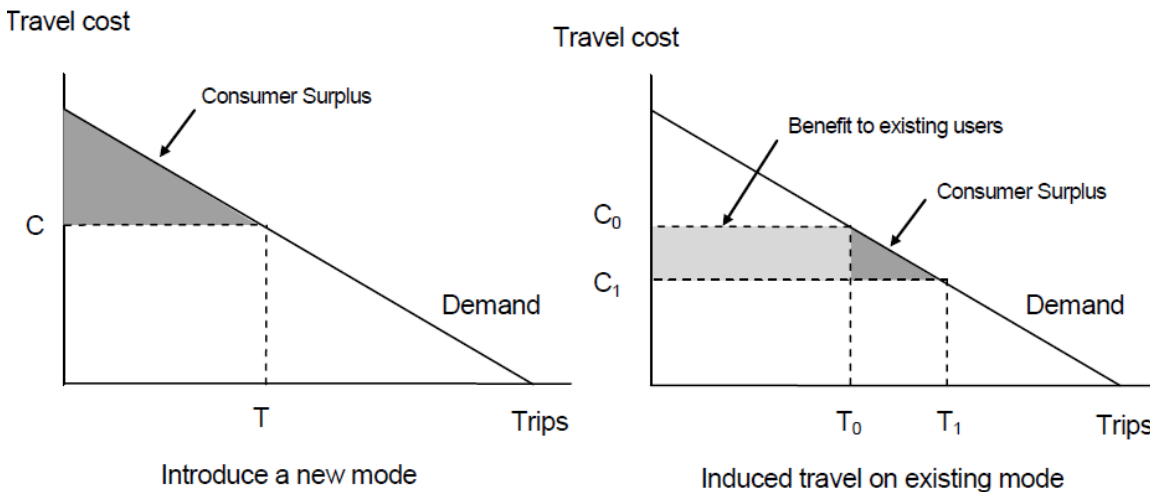
- The term 'manual' used in the name of this method suggests external calculations in a spreadsheet outside the demand model, which would typically be the way the method is applied. It is possible, however, for the demand model software to be extended to undertake the calculations within the model.
- The 'rule-of-a-half' makes the simplifying assumption that the demand curve is a straight line over the region of the generalised cost change associated with the initiative. This is a reasonable assumption only for relatively-modest changes in demand. Method 2 should therefore only be used where an initiative produces modest demand changes (see further discussion below).

When demand changes are large

When an initiative results in relatively large changes in travel demand, the associated curvature of the demand curve over this range may be significant. In these cases, the rule-of-a-half assumption of a linear demand is no longer reasonable, and the rule-of-a-half calculation stops being a good approximation to the change in consumer surplus.

Figure 5 shows two such cases. The left-hand side shows the case where a new mode is introduced, and on the right-hand side induced travel on an existing mode for a large demand change (T_0 to T_1). Methods 3 and 4 provide two methods for use in these circumstances

Figure 5 Consumer surplus for large demand changes

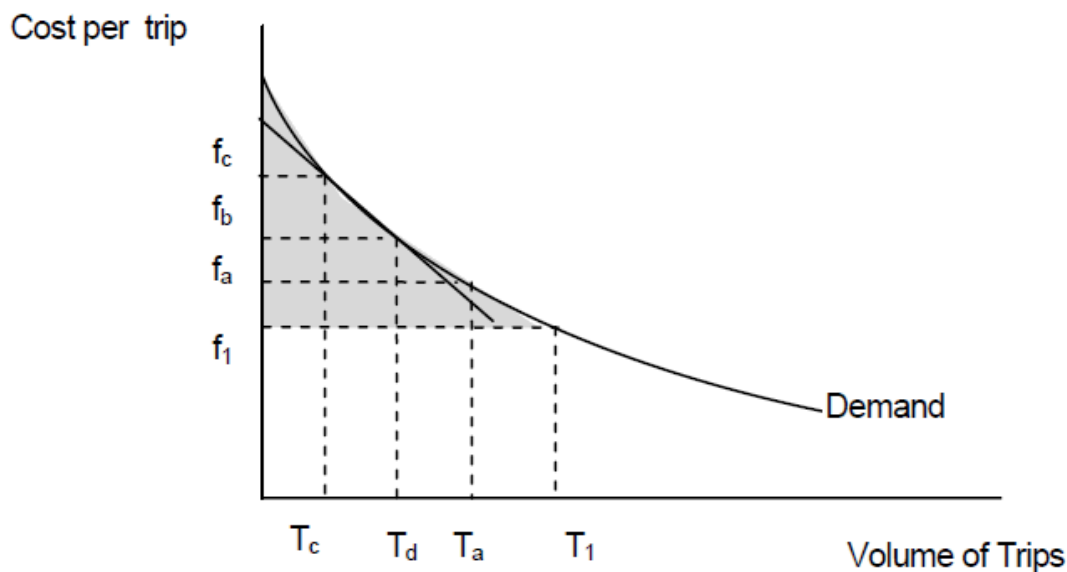


Source: TfNSW (2016, appendix 9)

B.3 Method 3 – Numerical integration – modified rule-of-a-half method using multi-modal demand modal

This method for assessing large demand changes first breaks the demand changes into a number of smaller parts (TfNSW 2016, Nellthorpe et al. 2001). Method 2 is then applied for each part of the demand change. In 5, that would mean application of method 2 for the demand changes 0 to T_c , T_c to T_d , T_d to T_a and T_a to T_1 . The overall change in consumer surplus for the initiative is then the combined results for the parts. This method is called *numerical integration*.

Figure 6: Numerical integration method



Source: TfNSW (2016, appendix 9)

B.4 Method 4 - Logsum method derived directly from multi-modal demand model

When using a discrete choice (also called logit) travel demand model⁵¹, a more direct, and more accurate, method of estimation of the change in consumer surplus is using the logsum⁵² measure within the demand model. Further details are provided in Appendix C.

The *logsum* method has several advantages over the other methods:

- it is theoretically the most correct method to estimate changes in consumer surplus where demand has been forecast using a logit model
- it draws more directly on information in logit travel demand models than method 2
- it calculates benefits by integrating demand curves for each mode between the Base Case and Project Case generalised cost levels to derive utility—it is therefore more accurate than any application of the rule-of-a-half (methods 2 & 3), although the improvement in accuracy would be smaller with method 3 than method 2
- it provides a curved demand relationship where the change in demand on an existing mode is sufficiently large that the demand curve is likely to significantly deviate from a straight line
- it provides a good estimate of total consumers' surplus where an initiative involves introduction of a public transport mode that currently does not exist and hence where the demand curve extends over a significant level of demand and is more likely to be curved.

The logsum method can be employed only where a logit travel demand model has been used to estimate demand. To confirm that the logsum approach has been correctly applied, it is advisable to check the result by making an estimate of the consumers' surplus gain using one or a combination of methods 1, 2 and 3.

⁵¹ The *logsum* method cannot be used in other circumstances.

⁵² See Appendix A below and also de Jong et al. 2005, Kohli et al. 2006, Zondag et al. 2007, Daly et al. 2008, Zhao et al. 2012 and Department for Transport 2014 for more information about this methodology.

The consumers' surplus estimate obtained by assuming linear demand curves should be greater than the logsum estimate, but not by a large amount, depending on the sizes of the price changes and use of method 3 to adjust for curvature.

The *logsum* method first calculates the change in utility (as represented in the travel demand model) for each assigned traveller, then aggregates the changes for groups of travellers and finally requires conversion of utility into a monetary value. More specifically, it measures traveller utility by calculating the natural log (ln) of the denominator of the logit mode choice model. The complexity of the calculation depends on the level of detail included in the travel demand model for the factors that affect travel decisions. The method also requires careful use of parameters to convert utility, which is the driver of travel choice in travel demand models and the initial measure of user benefits, to monetary values. The use of the approach becomes more complex when the marginal utility of money is not taken to be constant.

In practice, the calculation of consumer surplus using the *logsum* method is not complex for knowledgeable users because the calculation is undertaken entirely within the travel demand model.

The *logsum* method also has several disadvantages:

- Because the calculation is undertaken entirely within the travel demand model, there is reduced transparency in the calculation of benefits
- The theoretical complexity of the methodology is likely to make it less easily understood by non-modelling specialists
- The accuracy of the estimate of benefits will depend on the quality of the transport model and the parameters used to calibrate it.⁵³ At present the *logsum* method requires users who have excellent knowledge of travel demand models and economics to ensure its proper use.

The *logsum* method will become more valuable as travel demand models continue to become more complex, for example to include income effects, changes in departure time and more flexibility with regard to destination choice.

Appendix C has an extended discussion of the *logsum* method and its calculations.

⁵³ Which is true of the other methods as well.

Appendix C Logsum methodology

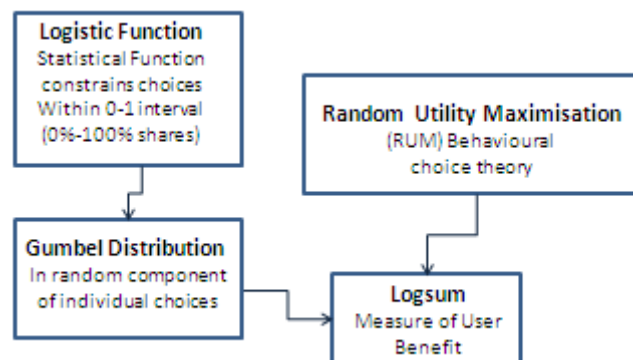
C.1 Definition of the logsum

The logsum brings together the logistic function (offering the practical advantage of keeping forecast shares within the 0–1 interval in a mathematically tractable way) and ‘Random Utility Maximisation’ which provides an economic basis for explaining the choices made by individuals.

The logsum is the correct measure of user benefit when a logit model is used. However, its ‘correctness’ relies on the acceptance of a particular distribution for the unobservable or random components underlying the choices made by individuals; this is that random components are independently and identically distributed in accordance with a Gumbel distribution.⁵⁴

The links between the logit function and the logsum measure are shown schematically in Figure 7.

Figure 7: Links between the Logit Function & Logsum User Benefit Measure



C.2 Logistic function

The logistic function was named in 1844 by Pierre François Verhulst, who studied it in relation to population growth (where growth was considered exponential in early stages then declining as a saturation level approached). The logistic function uses Euler’s constant ‘exp’ (or ‘e’) exponential (2.7183...) derived from continuous growth rates over very short time periods.⁵⁵

The mirror image (inverse function) of ‘e’ is the natural logarithm (ln) which is so named because of its frequent occurrence in mathematics. Taking the natural logarithm of an exponentiated number returns the number itself.⁵⁶

⁵⁴ Sometimes referred to as a Weibul distribution

⁵⁵ $e = \left(1 + \frac{1}{u}\right)^u$ where u tends to infinity. For $u = 100,000$, $e = 2.71827$. It is worth noting that similar shaped functions would result if values of 2, 3, 3.5 etc were used instead of ‘exp’.

⁵⁶ $\ln(\exp(x)) = x$.

Since its first reported use in 1959 by Luce, the logit model has become the dominant probabilistic choice model in urban transport demand forecasting. Its dominance can be attributed to its ease of computation as compared with the probit function which gives similar predictions but is based on the normal distribution and is therefore mathematically less tractable.⁵⁷

The standard formulation of the logit model is shown in equation A1. It can be linearised into the 'log-odds ratio' as shown in equation A2 which is useful for parameter estimation since linear regression can be used.⁵⁸ The model can also be rewritten as equation A3 with the denominator extendable to cover more than two choices.

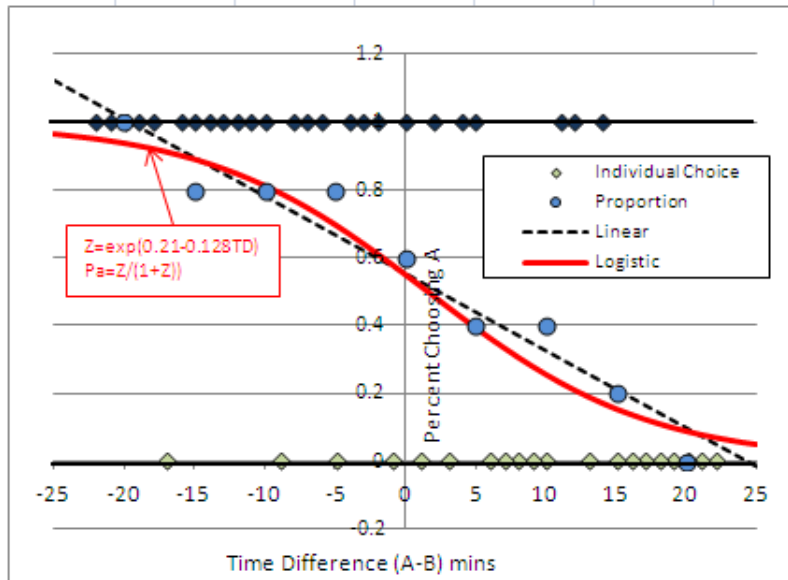
$$(A1) \quad P_a = \frac{1}{1 + \exp(-(\beta + \lambda(X_a - X_b)))};$$

$$(A2) \quad \ln\left(\frac{P_a}{1 - P_a}\right) = \beta + \lambda(X_a - X_b);$$

$$(A3) \quad P_a = \frac{\exp(\beta + \lambda X_a)}{\sum_i \exp(\beta + \lambda X_i)}$$

Figure 8 plots a logit curve for a choice of two transport modes A and B which vary in terms of the difference in travel time from A being 25 minutes quicker than B to taking 25 minutes longer. People can travel by A or B.

Figure 8: Predictions with a Logistic Choice Function



⁵⁷ The probit model which uses the normal distribution rather than the logistic distribution was applied much earlier by Thurlstone in 1927. It has a distribution similar to the logistic function but has fatter tails.

⁵⁸ For shares data when proportions are not zero or 1.

Individuals choosing A are shown as the dark blue diamonds along the top axis (a probability of 1). Individuals choosing B are the light green diamonds along the bottom axis. As can be seen more individuals choose A the larger the time saving but some still choose A when it takes longer than B. The aggregate proportions choosing A (averaged by five-minute period) are shown as the light blue circles and trend upwards from right to left showing the effect of the time saving more clearly.

The logit curve, fitted on the individual (1,0) observations using maximum likelihood, traces the proportions. The 'curve' is effectively a straight-line between 20% and 80% then flattens out so that the predicted proportion does not exceed 1 or fall below 0. The curve is symmetrical around its mid-point which in this example is 58% and not 50%. Also plotted is a linear probability function which crosses 0% (all choosing B) at 25 minutes and 100% (all choosing A) at -20 minutes and thus has the drawback that it would have to be constrained in application.

C.3 Random Utility Maximisation (RUM)

Much of the theoretical work around individual choice modelling was undertaken from the 1960s to 1980s when the theory of individual choice was developed and modelled.⁵⁹ This was particularly so for urban transport demand forecasting. Theoretical work grounded choice models on the principle of utility maximisation whereby individuals select the option that provides the highest utility.⁶⁰

To operationalise models, logit curves like Figure 8 were fitted. However as can be seen from the scatter of observations, predicting the exact choice of individuals is not possible. To explain and also utilise the 'error', the concept of random utility was developed.

Table A1 helps demonstrate the effect of random utility. Rather than maximise utility, the 'mirror image' of minimising transport time is shown. Service A takes 20 minutes and service B 30 minutes. Based on the observed times, service A should always be chosen. However unobservable random effects affect the choices made. The random component is distributed so that there is a 50:50 chance of adding or subtracting 10 minutes. The chance is assumed to be the same for A or B (same distribution) but is independent (no correlation between A and B). This produces four equally likely outcomes (rows 1 to 4). Three outcomes result in option A minimising the total cost and one outcome (2) results in option B minimising the cost.

Table A1 Observed and unobserved components of travel time (minutes)

Outcome	Observed		Unobserved 'Random'		Total		Minimum	Select
	A	B	A	B	A	B		
1	20	30	10	10	30	40	30	A
2	20	30	10	-10	30	20	20	B
3	20	30	-10	10	10	40	10	A
4	20	30	-10	-10	10	20	10	A

⁵⁹ A thorough discussion of the development of individual choice modelling and its application to urban demand modelling is provided in *"Forecasting Urban Travel - Past Present & Future"* by David Boyce & Huw Williams, Eddie Elgar Publishing 2015.

⁶⁰ Particularly noteworthy was the work of McFadden (awarded the Nobel prize for economics) who in 1981 demonstrated the conditions under which the logsum measured expected utility.

The expected received cost (maximum utility) is the average of the four minima (i.e. 30, 20, 10 & 10 minutes which is 17.5 minutes). This is less than either the minimum observed time of 20 minutes, the weighted average of 22.5 minutes (0.75x20+0.25x30) or the simple average of 25 minutes. Thus, by taking account of the unobserved random component, the received 'cost' is reduced below that of the observed times.

Of course, it will never be possible to measure the unobserved random component directly, but it can be 'inferred' once assumptions about the distribution of the random component are made. The logistic function in Figure 8 was based on the difference in the random components (i.e. A-B). To get this distribution, it can be shown that the random component of the individual choices (A and B) need to be independent and identically (iid) Gumbel distributed.⁶¹

C.4 Logsum measure

It can be shown that with iid Gumbel distributed unobserved random components (ε_i), the expected maximum utility (or minimum 'cost') is the logarithm of the sum of the exponential observed utilities (U_i), in shortened terms, the 'logsum' (equation A4):

$$A4 \quad \text{Exp}\{\text{Max}(U_i + \varepsilon_i)\} = \text{LogSum} = \ln \sum_i \exp \lambda U_i$$

To convert the logsum into minutes requires multiplication by the reciprocal of the mode choice sensitivity parameter (i.e. $1/\lambda$) (equation A5):

$$A5 \quad GT(\text{LogSum}) = \frac{1}{\lambda} \ln \sum_i \exp \lambda U_i$$

With the choices shown in Figure 8, λ was estimated at -0.128: thus with travel times of 20 and 30 minutes for A and B respectively, the logsum cost is 16.77 minutes (equation A6):

$$A6 \quad \text{LogSum} = \frac{1}{-0.128} \ln\{\exp(0.2 - 0.128(20)) + \exp(-0.128(30))\} = 16.77$$

⁶¹ The Gumbel (double exponential) distribution was named after Emil Julius Gumbel. It is a member of the family of extreme distributions as described by Gumbel in 1959. The Gumbel distribution is often used to model the distribution of the maximum (or minimum) values from a number of samples and has a shape similar to the normal distribution. The cumulative density function for a Gumbel randomly distributed variable with location parameter K is:

$\Pr(X \leq x) = \exp\{-\exp(-\lambda(x - K))\}$ with a mean ($\mu = E/\lambda + K$) where E denotes Euler's constant (E=0.5772) and with

variance $\sigma^2 = \pi^2 / 6\lambda^2$.

The logsum cost is therefore less than the weighted average of 21.84 minutes calculated by multiplying the predicted shares of 82% and 18% by the respective times of 20 and 30 minutes (equation A7).⁶² The logsum is also less than the minimum time of 20 minutes.⁶³

$$A7 \quad \Pr A = \frac{\exp(0.21 - 0.128(20))}{\exp(0.21 - 0.128(20)) + \exp(-0.128(30))} = 0.82 \therefore \Pr B = (1 - \Pr A) = 0.18$$

It can be shown that the logsum cost will never increase if new choices are added even if the times and costs are higher than existing choices.⁶⁴

The logsum will also be less than the minimum of the observed costs of the available alternatives which results from the 'unobservable random' component of utility. Reducing the size of the random component will reduce the difference between the logsum and the 'observable' costs and time measures.

There are three main sources for the unobserved 'random' component:

- Omitted service attributes or costs which vary randomly
- Measurement errors e.g. averaging of times/costs over a travel zone
- Random 'taste' variations across individuals (which can be reduced to some extent by market segmentation).

The size of the separation parameter (λ) reflects the net effect of the unobserved components. The smaller the parameter, the greater the importance in the unobserved random component and the greater the difference in the logsum from the observable cost measure.

If choices are perfect substitutes (with no unobservable random error), λ will be infinite (negative), the shares will be 'all or nothing' and the logsum will equal the minimum cost. If the observed times and costs explain none of the variation in observed choices, λ will be zero.

Finally, it is important to note that the resultant logsum can be negative and such results do produce consternation in the measure itself. For this reason, focusing on the change in logsum between the Base Case and Project Case rather than in absolute measures is recommended.

⁶² The figure does not take into account the Alternative Specific Constant (ASC) of 0.21 favouring option A which is equivalent to a time saving of 1.6 minutes.

⁶³ The ASC of 1.6 minutes could have been added to option B which would have increased the logsum to 18.41 minutes but left the shares unaffected. It could also have been shared (e.g. deducting 0.8 minutes from A and adding 0.8 minutes for B).

⁶⁴ By extension, removing a choice always increases the logsum. For example, removing choice B in the example would increase the cost from 16.77 minutes to 20 minutes.

C.5 Theoretical credentials and application

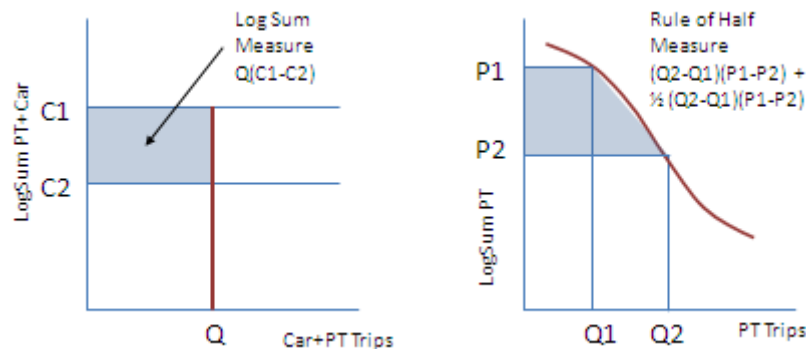
The logsum's credentials date back to the 1970s and 1980s when much of the theoretical work around individual choice modelling was made.⁶⁵ Of particular relevance was work by Williams, who in 1977 developed a suite of measures based around the logsum to measure user benefit for alternative formulations of the transport demand model taking account of route assignment and trip distribution as well as mode split.⁶⁶

However, despite the theoretical basis for the logsum measure, a review by RAND Europe for the Dutch Ministry of Transport found that it had been rarely used in project appraisal before 2000 (De Jong 2005).

Since, 2000, the use of the logsum has increased. In the US, the Federal Transit Administration (FTA) mandated the use of the logsum to measure user benefit as part of 'New Starts' project appraisal.⁶⁷ The FTA required that user benefit was calculated at the top of the mode choice 'tree' where public transport and car shares are forecast (equation A8). Thus user benefit (equation A9) included the effects on car users which might be positive if road speeds were increased (in response to patronage diversion to public transport) or negative (if road space was given up for a bus lane or Light Rail) and car speeds decreased.

To convert the measure into minutes, the log sum was divided by the in-vehicle time parameter (λ) used in the mode choice model. Benefit was therefore expressed in PT in-vehicle time minutes. Total benefit was calculated by multiplying total trips (PT + Car) by the logsum measure. The benefit measure was therefore rectangular in shape as shown on the left-hand side of Figure 9 as opposed to the more familiar rectangle plus triangle which would be calculated using the logsum cost for PT together with the change in PT demand which is shown on the right of Figure 9. It can be shown that the two measures will be close in size, the difference resulting from the discrepancy in the hypotenuse of the straight line and the logit share curve. Between 20% and 80%, the estimates will be very close since the logit curve is near enough a straight line. Only between 10 and 20% and between 80% and 90% will the estimates differ to any significant degree.

Figure 9: Log Sum Rectangular Measure



⁶⁵ If the 'random' components of the choices are correlated such that when the cost of one choice is high, the cost of the other choice is also high, the reduction in the composite cost as estimated by the logsum cost will be overestimated (the 'red bus/blue bus' problem).

⁶⁶ "On the formation of Travel Demand Models and Economic Evaluation Measures of User Benefit" HCWL Williams Environment and Planning March 1977.

⁶⁷ The "New Starts" program has been the US government's 'primary financial resource for supporting locally planned, implemented and operated transit guideway capital investments including commuter rail, light rail and bus rapid transit projects. To standardise calculations, a software package was developed called SUMMIT, which funding applicants were required to use until April 2013 when the funding approach was changed.

$$A8 \quad P_{PT} = \frac{e^{U_{PT}}}{e^{U_{PT}} + e^{U_{CAR}}}$$

$$A9 \quad GC_{PT+CAR} = \left(\frac{1}{\lambda} \right) \ln \{ \exp(\lambda GC_{PT}) + \exp(\lambda GC_{CAR}) \}$$

Where:

GC_{PT+CAR} = composite cost of public transport and car combined

GC_{PT} = generalised cost of public transport (expressed in PT IVT minutes)

GC_{CAR} = generalised cost of car (expressed in PT IVT minutes)

P_{PT} = probability of using public transport

λ = mode share sensitivity of PT demand to PT in-vehicle time

In Australia, the logsum has been used to estimate user benefits in a variety of contexts. Since 2011, Transport for NSW has calculated a composite generalised time measure using the logsum in the Public Transport Project Model (PTPM) which has been used to forecast patronage and demand side benefits of the North West Rail Link, CBD and South East Light Rail, Northern Beaches Rapid Transit, Newcastle Light Rail and Parramatta Road Improvement Program.⁶⁸

The logsum was also used to estimate the user benefits from High Speed Rail on the East Coast of Australia as part of feasibility studies for the Commonwealth Government in 2001 by Arup and TMG International and in 2011 by AECOM.

The measure has been used in smaller appraisals such as forecasting the benefit of a new rail station near Oak Flats in Sydney and assessing the impact on rail passengers of proposed new rail timetables for the Independent Transport Safety and Reliability Regulator of NSW.

The Institute of Transport and Logistics Studies, Sydney University has used the logsum to measure the accessibility improvement and the wider economy impacts of the North West Rail Link.⁶⁹

In New Zealand, the logsum has been used to calculate a composite cost measure of user benefit in the Auckland Transport Public Transport model since 2002.

C.6 Assessment

The logsum is a measure of composite cost for choice situations modelled using a logit choice model. It has demonstrable theoretical advantages over other composite measures such as a trip-weighted average time.

⁶⁸ PTPM includes a hierarchical mode share model (Public Transport Project Model) which is segmented by trip purpose. See Douglas and Jones, Developing a Suite of Demand Parameters for Inner Sydney Public Transport, Australasian Transport Research Forum 2016 Proceedings.

⁶⁹ "Assessing the wider economic impacts of transport investment with an illustrative application to the north-west rail link project in Sydney, Australia."

The conventional approach is to convert the logsum measure into a generalised time measure and only convert into dollars as a final stage calculation. In this way, it is possible to use behavioural values of time within the model and replace them by equity values of time in the economic Cost Benefit Appraisal.

The downside of the logsum measure is the difficulty in relating to its derivation and in this regard is much easier to understand user benefit calculations involving before and after travel times, costs and trips. Another issue is the fact that the calculated logsum can be negative and this result may cause consternation. It is therefore recommended to focus on differences in logsum (Project Case - Base Case).

Where it is decided to use the logsum, it is recommended that travel times, costs and trips are also output to enable comparisons with 'rule-of-a-half' measures for the overall system and for sample origin-destination pairs.

Appendix D Option values and non-use values

Section 4.8 of this volume provides advice on the circumstances in which option values (OV) and non-use values (NUV) should be calculated in the CBA of public transport initiatives, and where relevant, the appropriate methodology for estimating these benefits. This appendix provides supplementary information on the OV and NUV concepts and their relevance, summarises relevant individual research and appraisal procedures, and explains the recommended appraisal methodology and default benefit values.

D.1 Concepts and relevance

D.1.1 Option values

An option value (OV) represents the value (willingness-to-pay – WTP) to preserve the option of using a transport service (or facility) for possible future trips, or trips currently undertaken by other modes, over and above the expected value (consumer surplus) of any such future use.

Significant features of this option value concept include:

- Option values are associated with unexpected use of a transport facility which is not built into the forecasts produced by the modelling stage and would otherwise not appear in the appraisal as a benefit
- Option values are related to the individual's attitude to uncertainty — in practice a range of option values is likely to be found within the population
- There is a real risk of double-counting, particularly when trying to separate individuals' willingness-to-pay to have the option of using the service from their willingness-to-pay for their actual use of the service.

The literature also identifies a concept referred to as a quasi-option value. This represents the value of maintaining a facility until better knowledge is available regarding its future demand, which may be particularly relevant to decisions on whether or not to dispose of the track-bed or right-of-way of a closed railway. This concept is commonly incorporated within the wider option value concept.

D.1.2 Non-use values

Non-use values (NUVs) differ from 'use values' and 'option values' in that a value may be placed on the continued existence of a good regardless of any possibility of future use by the individual in question. The motivation for the desire for the good to continue to exist may vary: individuals may value a good for altruistic reasons, reasons of indirect use, or because the good has some existence or bequest⁷⁰ value. Examples of situations where NUVs may exist in a transport environment include:

- Use by other members of the household
- Use by friends or family
- Concern for other people in the community/society in general
- Concern for particular groups such the poor, the elderly, children
- Concern for future generations
- Desire to reduce congestion

⁷⁰ Existence values – a prominent example of non-use value, reflecting the benefit people receive from knowing that a particular environmental resource (e.g. Antarctica), endangered species or any other organism or thing exists.

Bequest value – together with existence value, makes up the non-use value of an environmental good or service – represents the value of satisfaction people receive from preserving a national cultural heritage for future generations.

- Desire to improve safety
- Desire to reduce environmental problems
- Social cohesion effects, such as links to larger communities
- Local economic or property effects.

D.1.3 Additionality and double-counting

In the context of project appraisal using cost–benefit analysis (CBA) methods, the OV is always additional to the consumer surplus from any actual use, and any environmental and safety externalities. NUVs, on the other hand, may double-count some elements of benefit already included in a comprehensive CBA appraisal. Only NUVs that arise from altruistic motives do **not** result in double-counting and therefore need to be considered for separate inclusion in a CBA appraisal. For example, the NUVs for a new rail line that is part of a plan to reduce road noise would already be included in a comprehensive CBA appraisal as a noise benefit, and should therefore be excluded as an additional NUV benefit in the CBA. However, a NUV that a resident may hold associated with ensuring the elderly can access facilities would be additional, and so included in the CBA.

Two substantial contributors to NUVs that would generally represent a double-counting of benefits and therefore should be excluded are:

- Changes associated with land or property values, which generally represent a capitalisation of the benefits conventionally appraised
- Changes associated with the profitability of businesses—i.e. the effect of a new transport service or facility on business profitability may be included in the appraisal as part of wider economic benefits, but typically involves a redistribution of economic benefits, rather than being a net additional benefit.

Other potential issues involving double-counting become apparent when the components of total economic value are identified. For example, care is needed to differentiate clearly between user benefits (including consumer surplus) and OVs—the former is the value associated with use of the actual service as it stands, and the latter is the value of having the service available for potential use in the future.

D.1.4 When do OVs/NUVs need to be considered?

In economic appraisal in the transport sector, OVs/NUVs are, in principle, applicable to road infrastructure and freight facilities as well as public transport services (including bus and rail passenger services).

However, OVs/NUVs are likely to be particularly significant in situations where strategies or plans being appraised include measures that substantially change the availability of transport services within the study area (e.g. the opening or closure of a rail service, or the introduction or withdrawal of buses serving a particular rural area).

The existence of OVs implies some scarcity or risk, as the presence of ubiquitous abundant services and facilities would naturally lead to a feeling of security and a very low value being placed on any particular marginal change in services.

The concepts of OVs and NUVs within the transport field have been developed in the course of studies of outer communities, where bus or rail services provide access for commuting (and other purposes) to a larger urban area. This type of situation is likely to result in relatively high OVs and NUVs being placed on the availability of such services. OVs and NUVs may also be significant in other situations, such as for isolated communities connected to larger centres by longer-distance services, or in locations within urban areas with poor public transport access or service levels. However, they are unlikely to be significant when assessing incremental changes in public transport services in typical urban situations with relatively good service levels.

For example, procedures in England and Wales specify that “*option and non-use values should be assessed if the scheme being appraised includes measures that will substantially change the availability of*

transport services within the study area (e.g. the opening or closing of a rail service, or the introduction or withdrawal of buses serving a particular rural area.” (DfT 2014a)

D.2 International research and appraisal procedures

Market research studies into OV/NUVs in the public transport sector have been undertaken internationally since the early 1990s, although reports on only around 10 such studies are found in the international literature. All research studies have adopted some form of stated preference (SP) survey approach, using contingent valuation (CV) or conjoint analysis (CA)/stated choice (SC) experiments.

A 2011 review of previous international studies for the NZ Transport Agency (Wallis & Wignall 2012) identified seven studies undertaken relating to OV/NUVs for public transport services from outer (peri-urban/semi-rural) areas into larger urban areas: four of these were UK-based studies, one in Netherlands, one in Italy and one in USA. The NZ Transport Agency work also involved primary market research to investigate OV/NUV for bus and/or rail services for outer areas in NZ. This work resulted in a suggested set of monetary values (\$ per household per annum) for the additionality component of OV/NUVs, varying by three scheme categories (according to level of service offered, quality of car alternative, etc.). Our understanding is that no similar studies have been undertaken in Australia.

The NZ research project also identified a number of other international studies undertaken to estimate transport OV/NUVs in other situations (i.e. not specifically related to public transport services from outer areas). These situations included inter-city rail passenger services (Korea) and a long-distance rail passenger service stopping to serve a remote community en route (NZ).

We also note a recent market research study to estimate the OV/NUV associated with the proposed Sydney Light Rail extension through Sydney CBD. To our knowledge, no comparable studies into OV/NUV in a central city area already served by numerous (bus and rail) services have been undertaken internationally. Given this, it is considered premature to offer any quantified guidance on OV/NUVs relating to such situations.

The clearest consideration of OV/NUVs is presented in the project appraisal procedures applicable in England and Wales, which specify that (DfT 2014a, WebTAG unit A4.1):

- OV/NUVs should be assessed if the scheme being appraised includes measures that will substantially change the availability of transport services within the study area
- Assessment should assign a qualitative score, based on the numbers of households affected (adversely or beneficially) from withdrawal or addition of the service under consideration
- In cases involving the opening/closure of local rail stations and the introduction/loss of good quality local bus services, a monetary assessment may also be undertaken
- A set of unit monetary valuations for OV/NUVs is provided with values (per household pa) depending on whether the services subject to assessment are by train, bus, or both
- In presenting the overall economic appraisal results, the main summary of project economic impacts should exclude any monetised OV/NUVs. However, these monetised values should be presented through sensitivity tests.

As far as can be ascertained, monetisation of OV/NUVs is not currently included in the formal economic appraisal procedures adopted in any countries other than England and Wales.

Appendix E Methodology for estimating public transport operating costs

This appendix supports Section 6.3. It is written in terms of buses but can be generalised to other modes.

Benchmark studies on methodologies to analyse bus and train operating costs in Australia were conducted several decades ago (R Travers Morgan 1978, R Travers Morgan 1980).

In practice, public transport operating costs need to be expressed as a function of at least three variables:

6. The number of vehicles required to meet peak requirements, typically with some overhead costs and costs such as depots and vehicle washing being a function of the number of vehicles in the fleet
7. The distance travelled, with costs such as tyres and a share of fuel and maintenance being related to the distance travelled
8. The time the vehicle is in operation, with costs such as driver and other crew time and some overhead costs and fuel consumption related to the distance travelled.

In the case of train services, the distance and time parameters should each be divided into a component related to train (i.e. consist) units and a component related to vehicle (i.e. car) units.

This composition of costs, if correctly derived, should generally reveal all changes in operating costs between options. For example, fuel consumption is a function of the time vehicles are in service and the distance they travel. A change that results in higher travel speed will show reduced operating costs due to improved fuel consumption. More complex operating cost functions can be derived to reflect these effects more precisely if data are available.

The annual costs of operating a bus service can be expressed as:

$$C = N_{pv} * C_{pv} + B_{km} * C_{bkm} + B_{hr} * C_{bhr} + RL * C_{rl}$$

where

C	=	total annual cost
N _{pv}	=	number of peak vehicles
C _{pv}	=	unit annual cost per peak vehicle
B _{km}	=	number of bus-kilometres operated per annum
C _{bkm}	=	unit cost per bus-kilometre operated
B _{hr}	=	number of bus-hours operated per annum
C _{bhr}	=	unit cost per bus-hour operated
RL	=	road length of bus route
C _{rl}	=	unit cost per km of road used by bus services.

For the appraisal of most substantial public transport initiatives, the costs that are of relevance are long-run costs: when comparing a Project Case and Base Case, the relevant cost differences are those that could be expected over the long-run. Experience indicates that, in the long-run, most categories of public transport operating costs are variable with some measure(s) of the scale of the operation.

The value of the cost parameters can vary substantially according to the type of service being provided, the average route length, the efficiency of the public transport agency and the size of buses used.

An illustrative derivation of unit costs for a bus operation, based on the bus company's financial and operational statistics, is presented in Table D1:

- The first part of the table indicates total annual costs (\$163 million overall) and their breakdown into major cost categories. It also shows the resource items with which each cost category is judged to vary (e.g. for fuel and oil) 50% of costs are variable with vehicle-hours, 50% with vehicle-kilometres. (Many operators and authorities assume that fuel costs are fully variable with vehicle-kilometres, but the assumption made in the table is probably more accurate for typical urban bus operations assuming a stipulated level of activity.) The table also shows administrative overheads as being 50% variable with vehicle-hours and 50% with the number of peak vehicles (both of which are useful measures of the scale of the operation). While such overhead costs are often treated as fixed (i.e. independent of the scale of the operation), this is unlikely to be the case, except perhaps in the short-term: over the medium to long-term, organisations generally should be able to adjust their overhead costs to match the scale of their operation.
- The second part of the table indicates the total annual resource statistics for the bus operation.
- The third part of the table derives unit costs by dividing the annual cost figures by the relevant resource measure. For example, for fuel and oil, the unit cost is estimated as \$5.06 per vehicle-hour + \$0.23 per vehicle-kilometre.

The costs in

Table 38: Appendix D - Approach to deriving bus operating unit costs D1 include only the operating costs involved in the provision of bus services. The capital costs of vehicles (including major overhauls) should be considered separately in an economic or financial appraisal. For economic appraisals, the actual capital costs of buses should be shown in the year in which the vehicles are acquired. For financial appraisals, the actual expenditures should be shown as the cash outlays would occur (e.g. in the case of a lease arrangement, the lease payments should be shown on a monthly or annual basis over the lease term).

Application of this approach requires information on the values of unit costs (C_{pv} , C_{bkm} , C_{bhr} and C_{rl}) for the local public transport agency, and values of operating statistics (N_{pv} , B_{km} , B_{hr} and RL) for the Base Case and the Project Case. Note that the unit costs would normally be the same in the Base Case and Project Case: any improvements in organisational efficiency should be achievable in the Base Case and Project Case. Exceptions may exist; however, they need to be carefully considered and justified. For example, a project might allow an institutional reorganisation that would not be otherwise possible and that could result in reduced overhead costs. While this may be possible, it may simply reflect an easy way to make an institutional change that should be made on the grounds of cost efficiency in any event.

Table 38: Appendix D - Approach to deriving bus operating unit costs

Cost component	Total annual cost (\$ million)	Allocated to:			
		Vehicle – hrs	Vehicle – kms	Peak vehicles	Road – km of route
Crew					
Drivers	74.9	100%			
Ticket inspectors	2.5	100%			
Operations					
Fuel and oil	18.2	50%	50%		
Tyres	1.9		100%		
Vehicle repair and maintenance	20.4	50%	25%	25%	
Vehicle cleaning	5.1			100%	
Despatching	2.0	100%			
Bus stop maintenance & information	0.6				100%
Depot maintenance	3.6			100%	
Overhead					
Administration	30.8	50%		50%	
Total	160.0				
Annual resources					
Unit		veh-hours pa	veh-kms pa	peak vehicles	road-km
Quantity		1,800,000	40,000,000	600	500
Unit costs (\$)					
Crew					
Drivers		41.61			
Ticket inspectors		1.39			
Operations					
Fuel and oil		5.06	0.23		
Tyres			0.05		
Vehicle repair & maintenance		5.67	0.13	8,500	
Vehicle cleaning				8,500	
Despatching		1.11			
Bus stop maintenance					1,200
Depot maintenance				6,000	
Overhead					
Administration		8.56		25,667	
Total		63.39	0.40	45,041	1,200
Unit		/veh-hour	/veh-km	/peak-bus	/road-km

Source: Based on a structure established by Ian Wallis. Values in the table are illustrative only, and do not reflect any particular enterprise.

Some agencies may have their own, particular approaches to calculating the operating costs of public transport in the Base Case and Project Case. The underlying objective is to determine the difference in the total annual cost of operating public transport between the Base Case and Project Case; whatever means are available can be used, provided they are applied consistently. It is, however, good practice to calibrate the unit costs to the transport agency to demonstrate that the total operating costs, based on the unit costs, are the same as the total operating costs for the agency.

A change between the Base Case and Project Case in the number of bus-kilometres travelled on the road system will result in a change in the amount of road wear (and the consequent need for road maintenance): this is a significant effect, given the relatively high axle loadings of buses. To a first approximation, the tax paid by bus operators on diesel fuel may be taken as a proxy for these road wear/maintenance costs. However, there is no comparable tax on CNG fuel. Therefore, where CNG buses are involved, an allowance needs to be added for the marginal road wear costs associated with bus operations. Typical marginal road wear costs of operating buses on urban arterial roads are around \$0.13 in mid-2014 prices (indexed up from \$0.10 per bus-kilometre in 2005/06 prices (updated from Bray & Wallis 1999, p. 258)). In the case of diesel buses, such an estimate could be used to replace the tax component of fuel costs if desired.

Indicative unit operating costs for bus, tram/light rail and urban rail operations in Australia are given in Section 6.7, and vehicle capital costs for each mode are given in Section 6.8.

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the 1990s, the number of people in the UK who are employed in the public sector has increased by 1.5 million, from 2.5 million in 1980 to 4 million in 1999. The public sector has also become an important employer of people with disabilities, with 1.5 million people with disabilities employed in the public sector in 1999, compared with 1.2 million in 1980.

There are a number of reasons why the public sector has become an important employer of people with disabilities. One reason is that the public sector has a long history of employing people with disabilities. In the 19th century, the public sector employed people with disabilities in a number of different roles, including as clerks, typists, and stenographers.

Another reason why the public sector has become an important employer of people with disabilities is that the public sector has a number of different departments and agencies, each of which has its own specific needs. This means that the public sector can employ people with disabilities in a wide range of roles, from clerical to professional.

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