Stage 1 Light Rail Business Case

Hobart to Glenorchy

Prepared for the Department of Infrastructure, Energy and Resources

May 2013

ACIL Tasman

Economics Policy Strategy

Reliance and Disclaimer

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Executive summary

This report examines the benefits and costs associated with the development of a light rail system (LRS) linking Central Hobart with Glenorchy. We examine four different optimal models, incorporating different trade-offs between speed and accessibility. On balance, the most rapid transit model is also the one which provides the greatest benefits, which is perhaps unsurprising given the locus of population at Glenorchy and of employment in Hobart and to a lesser extent Glenorchy.

The headline results of the analysis are shown in Table ES1 below. They suggest reasonable benefits from the development of the LRS, with benefit cost ratios of between 1.12 and 1.58 for the four and seven percent discount rate cases for the best performing model (with others slightly behind).

Table ES 1 **Benefit cost analysis – core results**

	Benefit cost ratio	Net benefit
OOSM 1: 3 stops fast system		
4 % disc rate	1.58	$44,326,000
7 % disc rate	1.12	$8,706,000
10 % disc rate	0.84	-$10,635,000
OOSM 2: 4 stops northern focus		
4 % disc rate	1.49	$37,697,000
7 % disc rate	1.06	$4,370,000
10 % disc rate	0.80	-$13,648,000
OOSM 3: 5 stops suburban focus		
4 % disc rate	1.49	$37,755,000
7 % disc rate	1.06	$4,376,000
10 % disc rate	0.80	-$13,680,000
OOSM 4: 6 stops high access focus		
4 % disc rate	1.21	$17,912,000
7 % disc rate	0.86	-$10,877,000
10 % disc rate	0.65	-$26,052,000

The results shown in Table ES1 are based upon some input assumptions which are "non-standard" in the sense of the ATC *Guidelines* (2006), although we believe the values used are defensible. Putting in the "standard" values for the relevant parameter with greatest effect, the transfer penalty, produces benefit cost ratios of zero; the project would need a transfer penalty of less than one minute to get a BCR above one (with a discount rate of seven percent, for OOSM 1). Additionally, the results are very sensitive to the value of travel time used; a sensitivity which, moreover, is asymmetric, with larger values of travel time reducing benefit cost ratios substantially, but decreases in travel time values not changing results substantially.

Costs

The light rail system is estimated to cost between $70 and $78 million (depending upon which OOSM is considered; OOSM 1 is the least expensive and OOSM 4 the most expensive). This translates to a real resource cost of $84 to $93 million when one considers (conservative) assumptions on the shadow cost of public funds. Annual operating and maintenance costs for OOSMs 1 to 3 are $2.3 to $2.5 million per annum in the first 20 years (when maintenance costs are smaller) and $3.2 million per annum thereafter. OOSM 4 has slightly higher operating costs, as it requires an extra driver and has slightly higher running costs due to the extra light rail vehicle (LRV).

Other costs

The report finds that there are likely to be other non-monetised costs, which are summarised in Table ES3.

Table ES 2 **Summary of non-monetised costs**

Cost	Description	Rating
Traffic delay during construction	Impacts on surrounding residents and on motorists from road closures, assuming construction is managed to minimise impacts.	Slightly detrimental
Traffic delay during operation	Impacts on road traffic from 11 signalised intersections with little conflict at present. Not in analysis because of a lack of a Hobart traffic model to make calculations easily.	Highly detrimental*
Impacts on bus services	Potential losses in economies of scale for Metro through competition on routes, mitigated by gains in economies of scale from feeder buses.	Slightly detrimental
Safety at Mawson Place	Dangers from mixing rail and pedestrians and cycling in what is now a pedestrian precinct.	Slightly detrimental
Opportunity costs of land	Land along rail corridor not available for other uses.	Slightly detrimental
Impacts on existing rail users	Gauge conversion costs for heritage trains	Slightly detrimental

** Note that we give this rating to motivate actual calculation using a traffic model. Subsequent calculation may indicate a lower value.*

Benefits

In this section, we provide an overview of the benefits associated with the development of the LRS.

Monetised benefits

We include the following monetised benefits:

- Changes in consumer surplus from a new transit mode being available and from the integrated feeder bus system.
- Producer surplus (operating profits) for the light rail system itself.[1]

Non-monetised benefits

The non-monetised benefits we include are summarised in Table ES4.

Table ES 3 **Summary of non-monetised benefits**

Benefit	Description	Rating
Social exclusion and access	The LRS provides some improvements in access compared to existing transport options, but the improvements are small given the widespread reach of existing bus services, whose frequency can be changed at a relatively low resource cost.	Slightly beneficial*
Improvements in social capital	If access is better, people are better able to access education, and thus improve their human capital. The same issue noted above about marginal improvements in access also applies here.	Slightly beneficial*
Employment effects	If access is better, people are better able to access employment. The same issue noted above about marginal improvements in access also applies here.	Slightly beneficial*
Heritage and culture	An LRS may destroy or create heritage and culture. Here, the proposed service does not appear to destroy any heritage sites, but may contribute to improving cultural values in Hobart, as there is some evidence that some stakeholders feel having a LRS announces that Hobart has “arrived” as a city.	Slightly beneficial
Health benefits	Catching the LRV involves more walking than driving a car, but the actual increases in walking, partly because of adroit design maximising convenience, appear to be small.	Slightly beneficial
Business travellers	We have no data on business to business travel by public transport in Hobart to calibrate this segment of demand. However, outside peak hours where there is no congestion, rail would be significantly slower than other modes unless both origin and destination are near an LRV stop.	Slightly beneficial
Savings from infrastructure	It is cheaper on a per person basis to provide infrastructure to a denser population. However, it is very expensive to dig up existing infrastructure to provide for increases in demand.	Neutral

** Note that people might not use buses because they do not like travelling by bus, even though a bus service of a similar frequency to the LRS is available. In the absence of issues such as public safety on buses (which does not appear to be a pervasive issue), our conclusions do not give weight to the fact that people might not like buses as much as they like LRVs. Others might argue that public policy ought to take into consideration what types of transport modes people like, but we would suggest that this could rapidly become very expensive for governments.*

Distribution of costs and benefits

In terms of distributional issues, we note that the LRS does traverse an area of relative socio-economic disadvantage in Hobart, and the feeder-bus system is designed to connect other, similar areas to the network in an efficient manner.

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[1] The light rail system makes operating profits, but it would not be a commercially profitable proposition, as a commercial firm would need to find the funding for the initial capital expenditure, and doing so would make the project uncommercial.

However, this same area is already well-served with buses. Some people near the main road enjoy frequencies better than the proposed LRS, many people enjoy frequencies (particularly in peak times) that are slightly worse, but people in outer areas only have access to relatively low-frequency buses. However, it may be possible to improve frequencies on existing bus services at a very low cost. Thus, the marginal distributional impact of the railway is relatively small above what could be done as a next best option; it is providing a second option to people who, in the most part, already have access to one (two, if they have a car) form of transport of a similar level of reliability.

We find in particular that claims made in the popular press about services on rail being an issue of social justice, and having a major contribution to unemployment in the region to have very little merit. In light of the fact that bus services exist (or could be relatively easily developed) which could provide similar levels of reliable transit to unemployed people in the region as could be provided by the LRS, the logical extension of this claim is that unemployed people do not want to use their existing transit options, and would prefer to catch an LRV. This seems an excessively pessimistic assumption about the preferences of unemployed people, and in the unlikely event that it is true in isolated cases, we would suggest that less expensive options to provide incentives to access employment could be provided before government considers building a light rail system.

As distinct from being unwilling to access buses, there may be some people who are unable to access a bus, but who could access an LRV, because of a particular disability they might have. However, the issue is that, based on admittedly incomplete data, there appear to be relatively few people in the immediate area of the railway who might fall into this particular category. At best there are around 150 to 200 people in the relevant area with a disability who either have some difficulty accessing existing public transport (most of the people in this cohort) or who cannot access public transport now but who might (the data do not suggest if they could access an LRV, only that they cannot access existing public transport options) be able to access an LRV. We would suggest that these people could be more effectively serviced by targeted community or para-transit also known as demand responsive transport options which meet their individual needs than a rail service which is less directly suited to their particular requirements but which might just prove adequate for them.

Sensitivity analysis

The sensitivity analysis involved an examination of changes in capital and operating costs, the value of travel time, the value of accidents, vehicle costs and externalities, changes in construction timeframes and changes in population growth.

Where changes were made on the cost side, the effects were roughly proportional to the scale, and only increases in capital costs reduced the BCR below one consistently.

Changes on the demand side, however, had very different effects. Most particularly, public transport is slightly slower than cars in Hobart (even after the LRS is built) and derives its marginal advantage in our core scenarios by having lower fixed costs (tickets versus parking costs, essentially). When the value of travel time increases, the small advantage in fixed costs for public transport vanishes, and demand for the LRS largely does as well; with BCRs dropping to below 0.15. This is potentially an issue for the LRS, in terms of a submission to IA.

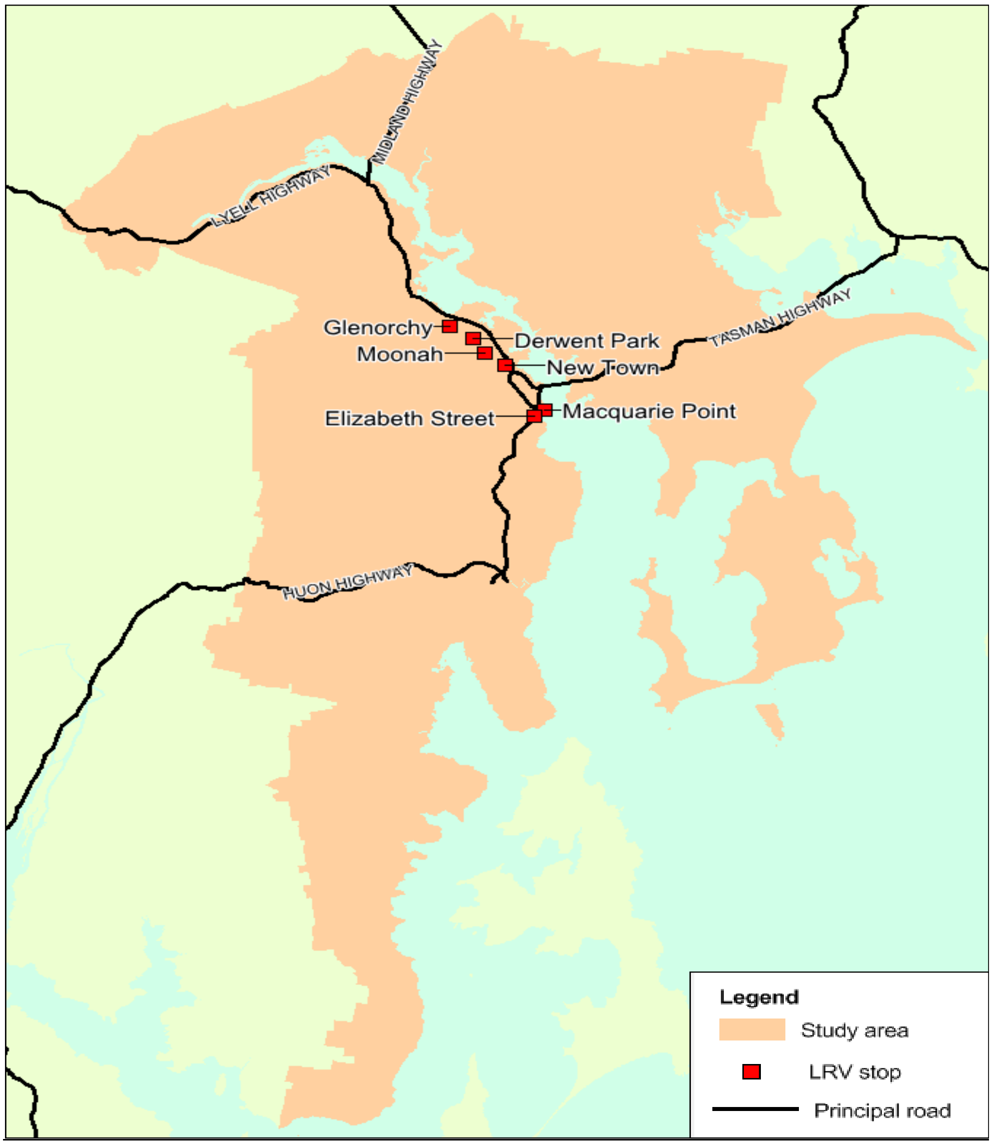
Information sources

The bibliography provides extensive detail on information sources used in performing this analysis.

1 Introduction

This report outlines an investigation of the likely costs and benefits of the development of a light rail link from Central Hobart to Glenorchy, utilising the existing rail corridor plus an on street extension to Elizabeth Street near Franklin Square. The report has been prepared for the Department of Infrastructure, Energy and Resources (DIER), to form background to a possible future submission to Infrastructure Australia for funding for the proposed light rail link.

Figure 1 **Map of project scope and study area**



There are two core elements to the assessment detailed in this report. The first is the calculation of a benefit cost ratio (and net benefits) and discussion of non-quantifiable benefits and costs as per the Infrastructure Australia (IA) guidelines. However, in order to assess such benefits and costs, one needs a projection of demand. To do this, and to use demand curves to assess the change in consumer surplus associated with the creation of the rail link, we make use of the Public Transport Economic Analysis Model (PTEAM) developed for the assessment of a different rail proposal in Hobart in 2011, and peer-reviewed by AECOM (2012).[2]

Chapter Two discusses the development of the Optimal Operating Service Models (OOSMs) that describe different ways in which the light rail system could be developed and operated. This discussion includes an overview of the costs of each OOSM, and the process by which these costs were developed. It is worth noting that each OOSM is not just a light rail link, but is rather a rail link combined with feeder-bus services designed to provide the same kind of seamless inter-modal transfer possibilities that have made the Perth to Mandurah railway (which likewise traverses relatively low-density population areas) successful. It is further worth noting that our demand modelling assumes that this feeder bus system is effective in achieving seamless transfer, (as in Perth) rather than assuming the existence of "transfer penalties", as would ordinarily be the case in a submission to IA. This has a significant effect on demand.

Chapter Three of this report provides an overview of the PTEAM model used in this analysis, with a particular focus on changes made to the model based upon the AECOM (2012) peer review and the comments of stakeholders at a workshop in Hobart on February 7th 2013. We would like to take this opportunity to thank workshop participants for their insightful comments.

Chapter Four contains the core of the report, the benefit cost analysis itself, and its relevant results. It is followed by Chapter Five, which discusses the non-quantifiable benefits. These should be considered carefully by policymakers, as this particular infrastructure ought not be considered in light of benefit-cost ratios alone. As part of the non-quantifiable benefits assessment, we provide a brief discussion of potential wider economic benefits from the railway. These are not strictly part of the scope of this review, and indeed are considered separately by IA. However, there has been considerable interest by stakeholders around some of these wider economic benefits, particularly agglomeration economies and possibilities for urban renewal and development, and we thus considered it prudent to go beyond the required scope of this report, and provide some baseline assessment which might later

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[2] see www.transport.tas.gov.au/miscellaneous/northern_suburbs_to_hobart_cbd_light_rail_business_case for both documents

be used to support a more detailed examination of wider economic benefits. Our findings in this respect strongly suggest very minor wider economic benefits.

Chapter Six contains a sensitivity analysis around the core results of the benefit cost analysis, to determine how robust they are to changes in assumptions. Chapter Seven contains our conclusions, Many aspects of the underlying analysis are highly technical, and we relegate discussion of these technical aspects of the analysis to appendices. Appendix B provides a more detailed overview of how PTEAM itself works (Appendix A is a bibliography).

Appendix C provides a literature review around the idea of productive use of time in transit; the notion that time in a light rail vehicle (LRV) is not simply "dead time". We use this concept to modify the "effective" journey time in the proposed light rail system compared to substitute trips in cars or buses to take account of the fact that people can do more productive activities in an LRV than they can in a bus, or when driving a car. Appendix B provides the background description of how we came to our conclusions on how to calculate "effective" journey time, based on findings from the literature.

Appendix C provides a review of the literature on agglomeration economies, leading to an explanation of the methodology we have used for our preliminary estimates of these in Section 5.4 of the report. The review is useful because it provides an overview of the very significant issues in the literature around agglomeration economies, explaining why they ought to be considered with extreme caution by policymakers (as IA suggests, but without the literature review to suggest why).

Appendices C and D provide background for certain aspects of the report, but also serve as useful source documents in their own right for further consideration of the two issues they cover.

Appendix E contains the engineering work undertaken by Hyder in developing the OOSMs, and Appendix F contains a proposed timetable for the Light Rail System (LRS).

2 Optimal Operating Service Models and Costs

The proposed LRS is a link between Central Hobart and Glenorchy (along the existing rail corridor), but there are various different ways in which this link could be designed. In particular, changing the number of LRV stops changes the nature of the service being provided, as does changing the frequency of LRVs running along the line. Each change alters the costs of the system (by needing more LRV stops and LRVs) and the benefits (by rendering the service more or less attractive to different groups of people).

We have endeavoured to account for the different operating parameters of the system through the creation of four different "Optimal Operating Service Models", (OOSMs). In this chapter, we provide an overview of the four OOSMs. These were developed to ensure that the probability of achieving the optimal benefit cost ratio (BCR) is maximised. The number of stops in the original business case 2011 was fixed. The selection of stops was based largely on opinions which were not tested for logic, nor was there any consideration of supporting bus feeder network immediately around or south of Glenorchy. With the shortening of the rail service the role of bus feeders play a far greater role to Glenorchy and LRV stops towards Hobart.

The purpose of the four core OOSMs is to establish what style of light rail services and bus feeder network is optimal. For example OOSM 1 represents the faster possible transit time to Hobart with the least number of stops, just Moonah between Glenorchy and Hobart. In contrast when moving through OOSM 2 through to OOSM 4 each operates with progressively more frequent stops allowing better access to services by feeder bus, walking or car but the time of transit to Hobart is slowed.

Each OOSM is not just a LRS option. If the LRS is to succeed, it will be vital that it is integrated with other public transport options, particularly buses, and that it has other opportunities for patronage such as park 'n ride or kiss 'n ride, access for walk-up patrons and provisions for cyclists. As such, we have included the costs of making the requisite accompanying investments and, in the benefit cost analysis, included the synergies which would eventuate in the event of such investments, such as smooth transfers between bus feeder services and light rail services leading to a higher attractiveness of the LRS. We have used as a basic conceptual model, the Perth to Mandurah railway line, which has exceeded expectations of patronage, whilst traversing a relatively low-density urban environment, by making effective use of seamless transfer between modes (see McIntosh, Newman & Glazebrook 2013).

The remainder of the chapter is divided into two parts. The first provides a description of each OOSM, and the second provides a summary of the costs.

2.1 Descriptions of OOSMs

In this section, we provide a description of each of the OOSMs. Each are fairly closely related to each other, and are based around the central notion of a line linking Central Hobart with Glenorchy, with a major bus interchange at the Glenorchy end, along with appropriate bicycle storage infrastructure and park 'n ride and kiss 'n ride facilities. Stops at Derwent Park Moonah and New Town will have facilities facilitating the easy transfer between modes as well a secure bike storage facility. The Hobart terminus is adjacent to major bus departure termini at the Hobart City Bus interchange with bus departure in Elizabeth Street and from Franklin Square (Macquarie Street). OOSMs differ primarily in the number of LRV stops and the associated adjustment of bus services to feed into such stops.

All OOSMs have feeder bus services with 15 and 30 minute weekday frequencies and all have the following operating times:

- 15 minute frequencies 7am to 6:30 pm
- 30 minute frequencies typically 6am to 7am and 6:30 pm to 7:30pm weekdays, as well as 8am to 7pm Saturdays and 9am to 6pm Sundays.
- At other times, for example at night time after 8pm when rail services have ceased, bus services will operate on a substitute route at generally half hourly intervals until midnight. These services will connect to selected feeder services.

The frequency and spread of hours has been carefully chosen to maximise patronage on the one hand and minimise costs on the other. A deliberate decision was made to not have an extended later night time service. At night the costs of LRV operation are higher as additional security is required to operate such services. At the same time demand falls rapidly and sufficient capacity would exist on bus services.

The terminus for all OOSMs is in Elizabeth Street (adjacent to Franklin Square) in Central Hobart, is opposite/below the existing Hobart City Bus Interchange. This is in contrast to the previous report, where the terminus was in Mawson Place. The new terminus has been chosen as it involves only a small additional cost compared to Mawson Place (proposed terminus 2011 study), and brings passengers closer to the centre of town. For the purposes the demand modelling exercise, the centre of Hobart is on Collins Street, and the mid-point between Murray and Elizabeth Streets. This was found by dividing the city into a rectangular grid, and counting the annual rateable value figures for non-residential buildings in each grid, and choosing the peak of the "hill" that results.[3] Our centroid matches almost exactly that chosen by Gehl (2010). Unlike the previous study, where we did not include a walk leg to the destination in the city, we include one from the terminus to this city centroid; adding a little over three minutes to the trip.

There have been minor changes to the locations of stops for which there are feeder bus services to ensure that the transfer is as seamless as possible.

The OOSMs and their differences are summarised in Table 1.

Table 1 **OOSM descriptions**

Number	Description	Included stops
OOSM 1	Three-stop fast system	Glenorchy, Moonah, Elizabeth St
OOSM 2	Four-stop northern focus	OOSM 1 + Derwent Park
OOSM 3	Five-stop suburban focus	OOSM 2 + New Town
OOSM 4	Six-stop high access focus	OOSM 3 + Macquarie Pt

The basic logic behind the construction of the OOSMs is to begin with the simplest model, and then add stops. This is because the simplest model has the lowest costs for the operation of a LRS. It is also because fewer stops means quicker travel times between Glenorchy and Hobart, the two major locations of population. Since travel time is core to a high BCR, it was considered appropriate to start with this model first. It should be noted that the progression through the OOSMs is not intended to indicate some form of staged construction, whereby the stops in OOSM 1 would be constructed first, and the other OOSMs added later. Instead, the basic division is between simple and gradually more complex models. We anticipate that the final model delivered on the ground may be an amalgam of several of the OOSMs above.

The OOSMs allow adjustment of bus feeder services. Compared to OOSM 1, OOSM 2 introduces a Derwent Park LRV stop which in part will substitute for bus services which can be reduced in frequency near Derwent Park and re-routed to the Derwent Park LRV stop to save running costs of a bus network. The placement of Derwent Park stop allows many potential passengers to be within an 800 meter walking distance of Glenorchy, Derwent and Moonah stops and thus attracting use of rail to undertake trips within, or to and from, this Northern area.

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[3] By this we mean the maximum point, where the adjacent cells are close to the maximum; to avoid choosing an isolated block which happens to have one valuable building on it. We avoid residential land uses because we are aiming to capture buildings in which people work. The geo-coded data on annual rateable value, the closest available proxy to employment at this very fine-grained scale, were provided by the Hobart City Council, whose assistance in this matter we greatly appreciate.

OSSM 3 allows a New Town rail stop which would open up access by walking and by inner city feeder bus services. The Macquarie Points rail stop in OOSM 4 provides a second Hobart Central Business District (CBD) stop and allows linkage to proposed developments at Macquarie Point and will substitute for walking trips. A stop at this site also provides operational advantages of placement of an optimal passing loop at the site and providing provision of a back-up facility in the event a vehicle breaks down at the Hobart terminus.

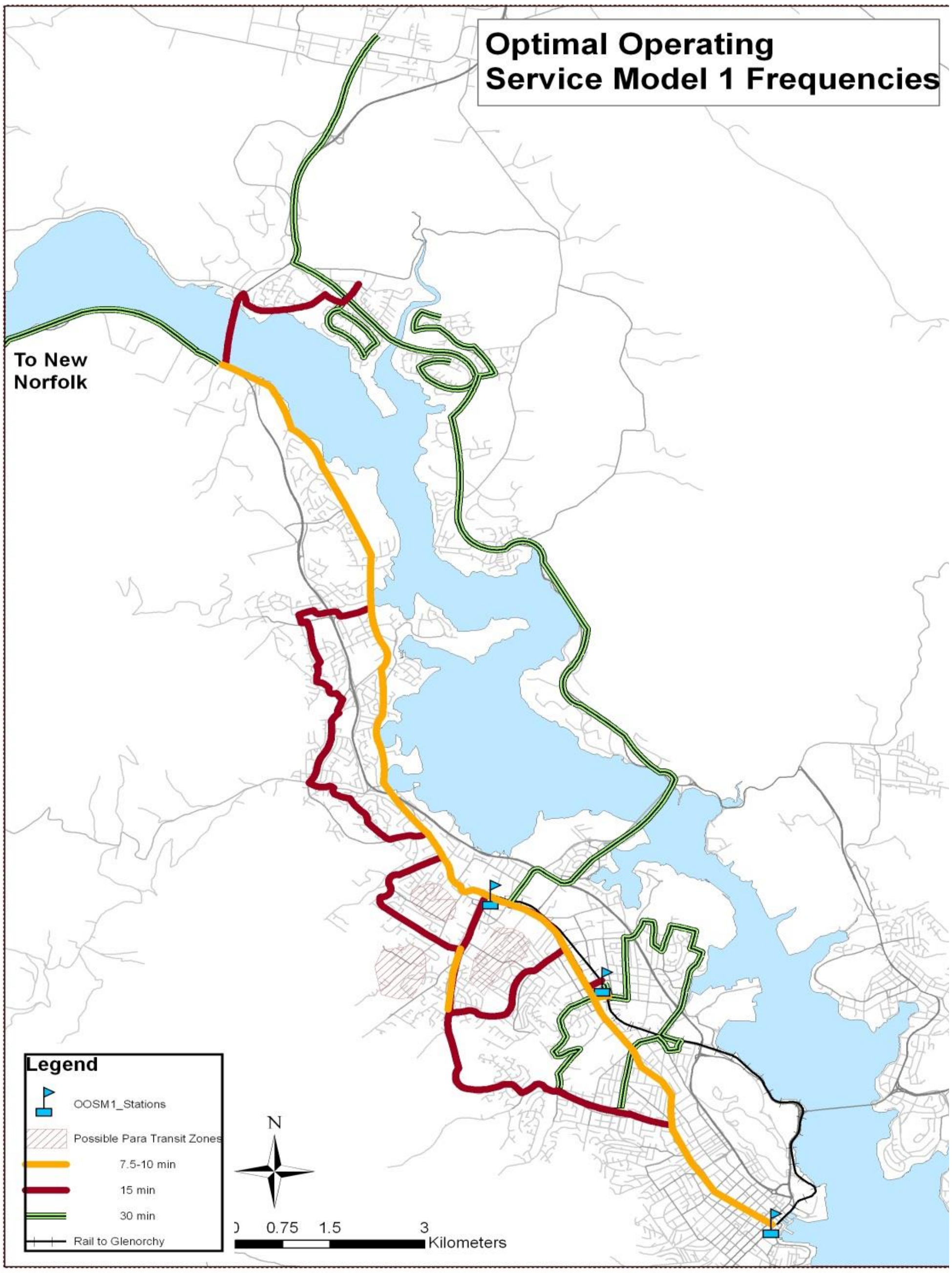
Feeder bus services in the OOSMS

As noted above, the OOSMs are not simply based on LRV services alone. Instead, they include the provision of feeder-bus services designed to integrate with the LRV services seamlessly in the same way that the buses and trains interact in the Mandurah and Joondalup railway lines in Perth. In the Australian Transport Council (ATC) *Guidelines* (2006), there is a suggestion that (at least) a five minute "penalty" ought to be applied for transfers between services, to account for the fact that people do not, in general, like making trips which involve a transfer. We are a little sceptical of such a large penalty; not only are most of the trips relatively short, but recent experience in Perth suggests that people are not so averse to transferring modes when the transfer is well-designed. Accordingly, we have applied a transfer penalty of zero for feeder buses in our model, though as the discussion in Section 4.2 makes clear, this is an assumption that makes a crucial difference to the benefits of the system.[4]

The feeder bus services that are proposed for OSSM 1 are shown in Figure 2. Note that we do not show all bus services in Hobart, but rather only the key services in the area which would interrelate with light rail services and are used for modelling purposes.

[4] This means that if there is a wait of two minutes between the bus arriving and the LRV departing, that two minutes is part of the overall travel time. What we do not do is add another five minutes to account for the fact that people suffer a disutility purely because they have to wait at a transfer station, which is what the ATC transfer penalty does.

Figure 2 **Feeder bus service frequencies – OOSM 1**

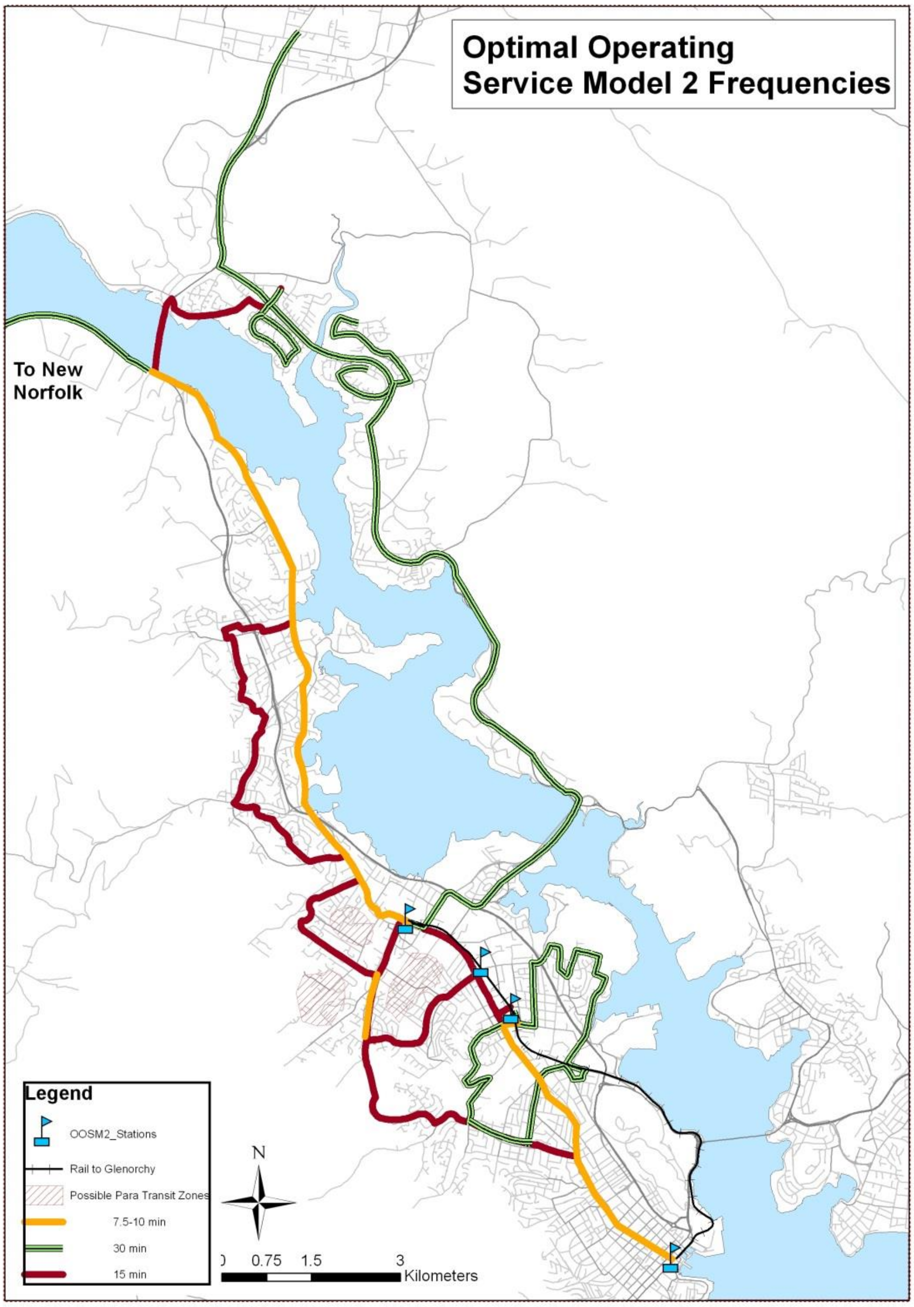


Source: DIER

The feeder bus services have been developed for OOSM 1 using the principle of cost neutrality. In other words the existing bus services have been redesigned and re directed to integrate with new rail services and operate at high frequency.

The location of Derwent Park LRV stop in OOSMs 2 through 4 reduces the overall cost of bus feeder service provision as the light rail service will at least in part substitute for bus services running between Moonah and Glenorchy to minimise their cost of provision, as well as to ensure smooth integration between the bus and LRV. Under OOSM 2 some feeder bus services terminate at Derwent Park LRV stop as opposed to Moonah LRV stop. The net effect of this is to reduce the operating costs of buses in Hobart by $350,000 per annum compared to their present level. This figure has been included in the benefit cost analysis. The OOSM 2 feeder services are shown in Figure 3; other OOSMs are broadly similar.

Figure 3 **Feeder bus service frequencies – OOSM 2**



Source: DIER

The bus system has been re-designed not only to optimise feeder services, but to replace high penetration (ie – services that "meander" through the suburbs to cover as many streets as possible) low-frequency services with low-penetration, high-frequency services. The change in the system results in some pockets of demand in outer Glenorchy and West Moonah being isolated and, in these instances, targeted para-transit services (or demand responsive transport services) are proposed, with their cost included in the model, to ensure continuity of access for these passengers in an area of hilly terrain where it may not be practicable to walk to the nearest high-frequency feeder bus service.

The new network features considerable improvements to services from urban fringe areas of Brighton and New Norfolk where services will operate at a 30 minute frequency, but on routes with less penetration than current services. All such Northern services will combine to provide a very high frequency public transport corridor from Granton down the main road to Glenorchy rail stop. In addition the existing high frequency main road bus service will continue to operate from Glenorchy to Hobart in OOSM 1 and from Moonah rail stop to Hobart in OOSMs 2 through 4. High frequency services will also operate from Bridgewater, Claremont, Chigwell, Rosetta, and around the Glenorchy and West Moonah area.

Other feeders will operate at a thirty minute frequency in the outer areas of Old Beach, Gagebrook or on lower demand feeders services around Moonah and New Town. These are a significant improvement on existing bus services.

2.2 OOSM Costs

This section of the report summarises the cost estimate associated with the OOSMs and amendments from the original business case undertaken in 2011. For further details on the cost estimates, assumptions, consideration of the terminus point in Hobart, rolling stock consideration and rail modelling undertaken for the four OOSMs, please refer to Hyder's report (See Attachment E).

In accordance with a preliminary assessment of the demand for a rail service the selection of options for the OOSMs targeted low cost solutions that provide comfort to passengers and comply with standard and safety requirements. The cost estimates prepared and issued for previous OOSMs have been revised to consider design changes and likely construction variances to the original scheme. The main changes are outlined in Table 2:

Table 2 **Main changes from previous light rail system model**

Design / Construction Change	Cost Estimate Adjustment
Reduced length of HLR, Glenorchy – Elizabeth Street	Adjust distance and area based calculations accordingly Remove all costs associated with works north of Glenorchy (bridge and level crossing upgrades, etc.) Reduce number of LRV's required Reduce maintenance costs Reduce operational costs (less drivers, etc.)
Reduced number of stops in initial stage	Reduce stop costs Reduce number of loops required
Extend HLR to Elizabeth Street from Mawson Place	Increase street construction costs Increase allowance for traffic / pedestrian interface works Introduce allowance for intersection modification Additional allowance for service proofing
Incorporate dual/ standard gauge	Increase clearing / stripping width Increase formation width and subgrade improvements Increase capping layer area Increase ballast quantities Allow for all provision of new track components throughout, no reuse assumed Reduce LRV purchase price Provide setup cost for future dual gauge if required
Annual Operational and Maintenance Costs	Scaled reduction in staff numbers to suit reduced operations including reduced service on Saturdays and evenings. Maintenance budget adjusted to reflect reduced line distance.

Data source: Hyder (2013)

The costs of each of the key OOSM parameters are outlined in Table 3 below.

Table 3 **OOSM Cost parameters ($'000)**

Cost Item	OOSM 1	OOSM 2	OOSM 3	OOSM 4
Capital				
Track	$32,801	$32,801	$32,801	$32,801
Depot	$3,100	$3,100	$3,100	$3,100
Stops	$2,901	$3,188	$3,476	$3,763
Urban design & Landscaping	$194	$195	$197	$198
Project management & design	$3,705	$3,732	$3,760	$3,787
Rolling Stock	$15,600	$15,600	$15,600	$20,800
Contingencies	$8,556	$8,594	$8,632	$9,814
Total Costs 2011 rates	*$66,857*	*$67,211*	*$67,565*	*$74,263*
Total Costs 2013 rates	*$70,200*	*$70,572*	*$70,943*	*$77,976*
Annual Operating Costs	$2,164	$2,164	$2,164	$2,479
Annual Maintenance Costs				
Years 1 to 5	$101	$101	$101	$101
Years 5-10	$191	$191	$191	$191
Years 10-20	$334	$334	$334	$334
Years 20+	$1,080	$1,080	$1,080	$1,080
Net savings to bus system	$-	-$348	-$348	-$348

Data source: Hyder (2013) and DIER

Assumptions underpinning costs

The rail costs are based on 8.6km track length from Glenorchy to Mawson Place. An additional 400m are added to allow provision for two passing loops on the line. Further costs have been developed for the street extension from Mawson Place to Elizabeth Street. This includes allowance for traffic management, intersection modification, complex track and overhead line equipment installation. Depot and stop construction costs have remained consistent with the original business case, with an increased allowance for Elizabeth Street terminus to account for any additional road works associated with the new location.

Rolling stock costs have been revised based on current market conditions (2013) and recent LRV orders. The opportunity to procure rolling stock 'off the shelf' or second hand led to a review of the option to provide standard gauge track. LRV's are more readily available with standard gauge bogies and opens up opportunities to utilise existing rolling stock from other cities. It would cost less to construct a standard gauge LRV compared to developing a narrow gauge version with bespoke bogies.

The choice of gauge to be adopted will be dependent on the price and availability of any rolling stock at the time of construction but currently it is assumed that standard gauge is the preferred option because of cost savings in

LRV procurement. All other assumption remain the same as documented in the original business case.

Differences from previous work

The costs have been standardised to incorporate a new rail asset in all four OOSMs. This includes new subgrade, capping, drainage, ballast and track components. Although this option increases the initial capital cost per km, the benefit is a new asset which should prove more reliable with a lower maintenance cost through the first 25 years of operation.

There has been a reduction in the projected capital cost of the project of a little over 30% compared to the 2011 review. The route length has been reduced by around 40%, however some of the larger cost items such as the street construction in Hobart, electrification, bus interchange and the maintenance facility are still associated with the project. The revised costs are based on the previously prepared cost estimates detailed in the 2011 Business Case report, and 5% has been added to account for construction cost increases since 2011.

Construction costs are lower than in other capital cities (see AECOM, 2012), but the proposed light rail system is not directly comparable with other new projects currently proposed in Australia. The project is able to benefit directly from the receipt of an existing rail corridor. The existing freight corridor does require upgrading to permit the safe transit of modern LRV's at speeds which provide competition to road traffic, however this can generally be delivered at a lower cost than identifying and constructing a brand new light rail corridor.

In addition, the amount of street-running in the project is relatively low (less than 1km). This reduces the overall construction costs, traffic management and complexities of the project, which helps achieve a capital cost that can be expected to be lower than other new light rail schemes proposed in Australia.

Process of developing LRS costs

The cost has been built up by escalating existing cost data utilised on similar track reconstruction projects, such as the Glenelg Tram to Light Rail upgrade in 2005. This project involved the upgrade of an existing light rail corridor including new concrete sleepers, level crossing equipment, stops and improvements to the overhead line equipment. The costs also included upgrades to existing and construction of new urban street sections, which have also been used to verify the costs proposed in this project. The data used from older design / construction projects have been escalated to 2013 costs accordingly. For further information please refer to Hyder's report (see Appendix E).

3 Development of demand projections

In order to assess the benefits and derive a benefit cost ratio, one must first have a projection of demand, and an understanding of the net benefit each passenger of a new service receives relative to the transport options previously available to her. Unlike other cities, Hobart does not have a detailed traffic and transit model, nor consistent travel survey data which might be used to project demand. As such, a model capable of making demand projections, at least at the level of detail required for economic analysis, needed to be developed. This is the PTEAM model, developed in 2011 for our original work, and we have extended PTEAM for the current project, developing some new, more sophisticated treatments of certain aspects of the model, and taking on board comments from AECOM (2012) in its peer review of our original work, and from the stakeholders who attended our briefing on February 7th 2013 in Hobart, and gave valuable comments about many of the parameters which go into the model.

In this chapter, we describe how PTEAM works in the context of this assessment. The chapter has three key components:

- A brief overview of how PTEAM operates.
- A discussion of methodological changes.
- A discussion of changes to parameters.

The latter two dot points are perhaps a fine distinction. PTEAM is based upon a particular set of inputs; associated with different aspects of the decision to make a trip. In some cases, the inputs have changed because new information has changed the way we, the modellers, consider a particular aspect of the model. However, in this instance, we do not consider this to be a methodological change per se, because the underlying structure of the model is still the same. With this caveat about the interchangeability between the last two dot points in mind, we turn now to a discussion of PTEAM and its changes.

3.1 PTEAM – Brief overview

In this section, we provide a brief overview of the operation of the PTEAM model which provides the demand forecasts that underpin our benefit-cost assessment. Further technical details on the model are provided in an appendix. The estimation of the benefits in a cost-benefit analysis is grounded in the notion of consumer surplus (see Harford, 2006 or Winston & Maheshri, 2007 for two transport examples). Technically, the (net) consumer surplus is the area between the demand curve and a horizontal line at the prevailing market price. It reflects the fact that, since the prevailing market price is formed by the interaction between the marginal consumer (and producer), most people will pay less for the good or service than they would have been willing to pay, and thus obtain a "bonus" or consumer surplus when they consume the good (see Box 1 for more details). The PTEAM model is designed to directly calculate consumer surplus and, more pertinently, the change in consumer surplus which eventuates when a particular transport policy is implemented; here the construction of an LRS.

Box 1 Consumer and producer surplus

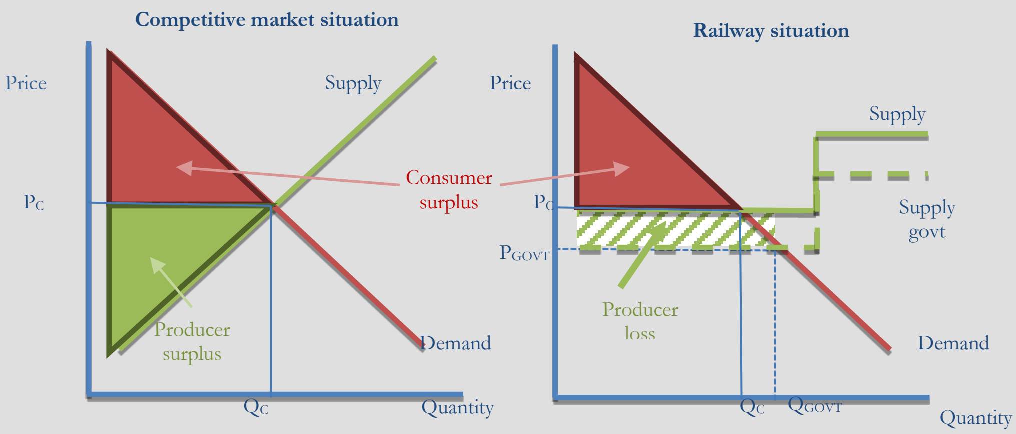
In a competitive market, a firm produces the quantity Q_C, which it sells for the price P_C, generating the red consumer and green producer surplus shown in the left-hand side of Figure 4.

For a railway, the situation is different. Not only is it usually the only provider of rail services in its jurisdiction but, more importantly, its supply curve has a different shape. Most of the costs of a railway are fixed, and thus the supply curve (here of the single railway firm) is flat (or close to it) over a wide range of output.

If government determines that the price of passenger railways should be less that the price the railway would like to charge to cover its costs, say a price of P_{GOVT}, which increases supply to Q_{GOVT}, the railway operator will suffer losses (the hashed rectangle below). These must be covered or the railway will not function. Usually, this occurs through the provision of grants from government; a subsidy for the railway.

Just as in the left-hand side of Figure 4, the total benefit to society of the good being produced is the sum of the consumer and producer surpluses, in the right hand side it is the sum of the positive consumer surplus and the negative producer loss which comprises the relevant social benefit of the railway being proposed.

Figure 4 Graphical representation of consumer surplus



Note that the consumer surplus in the right-hand diagram extends down as far as P_{GOVT} and across as far as Q_{GOVT}, but is obscured by the losses shown for the producer.

In order to calculate the consumer surplus before and after the development of the LRS, we need first to derive a demand curve, for all modes of travel separately, before and after the development of the railway.

To construct this curve, we used a model of consumer choice. We identified the different modes of transport available, for a representative consumer in each of 535 Statistical Area 1 (SA1s) (as defined by the Australian Bureau of Statistics - ABS) in Hobart. Note that this differs from our previous work, where only the Northern suburbs of Hobart were included. We calculated the cost to the consumer of using each of those transport modes (and combinations thereof; park 'n ride, for example, has a car, then a rail leg) for a specific trip; either a commuter trip to the City Centre, Glenorchy, Kingston, Clarence or Brighton,[5] or a leisure trip to a much wider variety of locations (see Appendix B for more details). The cost model is based directly on the work of Parry & Small (2009). Its elements include cash costs, the value of the time taken to make the trip, risks of accidents and pollution costs. The costs were calculated in a functional form, which allows for variation in the components, such as the value of travel time. It is this variation which provides the basic data upon which to base the demand curve.

The trips the relevant consumer can take are:

- Rail (walk to LRV stop)
- Bus (walk to bus stop)
- Car (includes the cost of parking the car)
- Feeder bus to LRV stop, then catch LRV
- Park 'n ride (driving to the LRV stop and catching a train; also incorporates kiss 'n ride, where the person is dropped off).

In each trip type, where relevant, there is a walking leg as well; from the home to the bus/LRV stop and from the light rail system terminus to the place of work in the city. There are also weights applied (see Appendix B) to different types of time to reflect relative utilities. These weights come from the ATC (2006) and are used as "standard" in benefit cost analyses to IA.[6]

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[5] The split of trips is Hobart 54%, Glenorchy, 20%, Brighton, 2%, Kingston, 9% and Clarence 15%, based upon employment location information from the latest Census. Light rail commuter trips can only terminate in Hobart or Glenorchy; the ends of the line. There is no scope in the model for a trip on the LRV, and then a switch to a bus (though bus to LRV is an integral part of the model). This is a shortcoming, but in reality, for a location outside Hobart or Glenorchy as a destination which represent a relatively small proportion of trips, there is usually a bus option that is as fast or better than getting to a LRV stop (by bus or walking), getting on an LRV and then transferring to a bus.

[6] This does not mean they are right. We have already discussed transfer penalties, but we are suspicious about some of the other "benchmark" values. They are referenced in ATC (2006), but the bibliography which highlights where each weight comes from lists many

The policy change being evaluated is the construction of a proposed light rail system. However, we have assumed that the existing bus system would change with the advent of light rail, to provide efficient feeder routes to the stops on the LRS. The costs of changes to the bus system have been included as costs in the benefit cost analysis, and the changed routes in the trips types above. The changes to the bus system are shown in Figure 2 (Section 2.1).

To conduct one "run" of the model, for a representative consumer in a single SA1, we choose a set of values for each of the elements of the cost function (a travel time cost, a fare etc.) for each mode and then compare the costs of making a trip based upon this set of values. We then assume each consumer minimises the total resource cost of a trip, by taking the lowest cost option available to them.

We record the choice of mode and the resource cost/quantity combination on a scatter plot for the mode chosen. We then choose another set of inputs, and repeat the process; in total around 1000 times. This results in a scatter plot of choices for each mode.

We then fit a demand curve to each of these scatter plots via regression analysis, and calculate the area under each demand curve up to the region-wide average resource cost. The sum of the surpluses after the construction of the railway is subtracted from the sum of the surpluses prior to its construction, and any necessary subsidies are subtracted from this result.[7]

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reports as "published" when they are in fact consultant reports to government departments or working papers from academia, rather than peer-reviewed papers. A better example of a peer-reviewed meta-analysis which makes use of peer-reviewed papers for its sources is Wardman (2004), which derives a similar set of weights for use in the UK. It does not appear that work of this calibre has been done in Australia.

[7] This is not quite correct. Most of the customers for the LRS come from cars, meaning that the demand curve shifts inwards for car drivers remaining on the road, and thus that the aggregate consumer surplus for car drivers falls because there are fewer of them (for individuals who switch, their consumer surplus increases, and this is recorded as an increase in the aggregate consumer surplus for public transport). We ignore this drop in consumer surplus for car drivers. The reason for doing so is that the consumer surplus is the area under the demand curve from zero to intercept with the supply curve (here the region-wide average cost). However, the model does not produce any observations of price-quantity combinations for cars that are near zero; because for all conceivable input prices, there are several tens of thousands of car trips. There is statistical variation around any demand curve, which does not matter much "in sample" (where the data points lie). However, once one extrapolates out of sample, small statistical errors get magnified, and this is what happens when the demand curves for cars are extrapolated back to zero trips. In fact, the magnification is so large that the drop in aggregate surplus for car drivers is larger than the gain for all other modes; a logical impossibility given that people would only choose to switch modes if they experienced an improvement from doing so. Once could argue that the remaining drivers on the road experience an increase in per-driver utility because there are fewer cars on the road (a dynamic fact that our model does not pick up) and thus that some of the modelled drop in aggregate consumer surplus for car drivers ought to be ignored. However, ignoring all of the drop as we do, which we do because of reasons of

We account for the fact that the urban form is likely to change in response to the development of the light railway by assuming that "transit oriented development" (TOD) zones will be established around four LRV stops, and people will move to these zones, creating an urban density equal to that of Subiaco in Perth (one of the more successful of these zones in Australia). This is discussed in more detail in Section 3.2, but it means in effect that ridership increases faster than population growth because people move to TODs in order to access the new public transport options available there.

3.2 PTEAM methodological changes

There are two main sources of changes to the PTEAM model compared to its previous iterations. The first of these is a different way of non-directed travel including discretionary trips such as leisure, shopping, personal business, visiting etc. The second is a series of changes in response to the AECOM comments on our original work. Both are detailed below.

Non-directed model changes

In the previous iteration (ACIL Tasman, 2011) every relevant person made a round trip journey covering a pre-defined distance in the mode associated with the lowest total resource cost. While it robustly predicted mode shares the model did not analyse travel patterns. For this iteration we developed a gravity model for the Hobart non-directed travel market.

The gravity model comprises nine key destinations, each associated with a certain intrinsic attractiveness.[8] This intrinsic attractiveness can be interpreted as the frequency a person would visit a certain attraction if the cost of travelling to all attractions was identical. Since this is usually not the case, the intrinsic attractiveness is adjusted by the cost associated with travelling to each attraction. This means that every representative consumer has a different travel pattern. The individual travel patterns can change when the (public) transport network is altered.

For example, suppose there are only two destinations (say A and B) with an identical intrinsic attractiveness. A person who lives right in the middle of the two destinations would visit A as often as B. For a person whose travel costs to A are twice as high as those to B, the travel cost adjusted attractiveness of A would a third of B's. Hence, for a total of say 100 trips, the second person

statistical validity associated with the demand curve for cars extending a long way out of sample, means that we almost certainly over-estimate the benefits associated with the new light rail service. This ought to be kept in mind when interpreting our results.

[8] This is based on feedback from DIER; there are no data that we are aware of of the intrinsic attractiveness of different locations in Hobart.

would go to A 25 times and to B 75 times. If the transport network was changed such that the second person's travel cost to A are reduced to 1.5 times those to B then the travel pattern would change and this person would travel 33 times to A and 67 times to B. Translated to the Hobart context, this means that a person living in Bridgewater might spend most of her time in Bridgewater, because trips to central Hobart are too expensive. The introduction of a new means of transport which makes travel to Hobart less costly would enable this person to go to central Hobart more often. [9]

The calculation of net benefits in the non-directed demand model works slightly differently to the directed model, and in fact in a manner more similar to a "standard" cost benefit analysis, by considering the average saving for those who switch, rather than calculating a change in consumer surplus. This is due to the internal mechanics of the non-directed model.

The issue is the fact that people can switch destinations in the non-directed travel models, which means that, even within a given scenario (before the railway, say), in the random draws where travel costs are high, they might choose a nearby shopping centre, but where travel costs are low, they might choose one further away. The discussion in Appendix B covers this in more detail, but the net result is that several demand curves exist. There are ways to treat this issue empirically, but there are no data on non-directed travel in Hobart that are sufficiently detailed to calibrate the model adequately. We consider that a very sophisticated model which cannot be shown to have any bearing to reality because of a lack of data is not a very good tool for transport policy, and thus use our simpler approach above.

Change from AECOM peer review

AECOM made a number of comments on our original model, and we have subsequently made changes to the model in this iteration to reflect these comments. Methodological changes are detailed below. In cases where AECOM suggested a particular parameter was too high or too low, we have made changes (where relevant) which are detailed in Section 3.3.

Development speed for transit oriented development

In our previous report, we assumed for the purposes of modelling that four TOD regions would develop around stops, to a density equal to that of Subiaco in WA, and that they would do so in the first five years. This was noted as being very rapid, and AECOM, quite correctly, suggested it was much

[9] Given the intrinsic attractiveness of central Hobart is higher than that of Bridgewater. This is the case in the model.

too fast. For this reason, we have changed our approach towards the development of TODs.

As part of its IA submission for funding for its redevelopment of Macquarie Point, the Department of Economic Development (DED) commissioned a study of likely demand for residential, commercial retail and tourism property sectors.[10] This included different housing types and different regions in Hobart, although its main focus was on Macquarie Point. The study was based upon projections of population and economic activity, and covered 20 years of likely demand for housing. Their conclusions for units (apartments and other medium density housing units common in a TOD) are shown in Table 4 below.

Table 4 **Projections for unit development in Hobart**

	Average annual demand			
	2011-15	2016-20	2021-25	2026-31
Inner Hobart	30	38	47	58
West	87	101	103	103
North	99	103	104	103
South	23	22	22	22
East	44	41	40	39
Total	282	305	315	325

Data source: AEC Group 2012). Note that this reflects the middle scenario; the high scenario sees 382 units per annum being built and the low scenario 195.

The area termed "West" covers the slopes of Mt Wellington, but also the area down to the shore in New Town (the border is roughly Risdon Rd). The area termed "North" extends northward past Brighton, but the main areas of activity for unit development are between Glenorchy and Moonah.

The results shown in Table 4 do not take the development of the LRS into account. To account for the development of TODs in the model, we assume that there are no changes in migration or outside investment (in housing) compared to the modelling undertaken by the AEC Group (2012) for DED, meaning that Hobart does not become more attractive to migrants from elsewhere in Australia or internationally because of its LRS and thus that it does not result in housing units being developed which would not be developed absent of a light rail system in the city as a whole. We further assume that it does not make units more attractive relative to other forms of housing, as we assume detached houses face a different demand compared to units. Both of these assumptions mean that the total demand for units in Hobart as a whole remains constant at around 300 units per annum; roughly a

[10] We would like to thank DED for making this study available to us.

fifth of all housing demand going forward. We assume rather that our study region becomes more attractive relative to the rest of Hobart for the construction of units. We assume that, instead of the roughly 100 units per annum shown in Table 4, it captures 150 units per annum of new development.

Since these new units are assumed to be developed within TOD precincts, we consider Census SA1 areas around the proposed stops at Glenorchy, Moonah, New Town and Derwent Park.[11] We then compare their current density with that around Subiaco station in Perth; a very successful TOD, and ask how long it would take to increase the density of these areas to the level of Subiaco, building 150 units per annum (spread across the four sites) and placing 1.4 people (the number of people per residential unit in Subiaco) in each unit as it is developed. The answer is 20 years. Thus, we assume for our modelling, that 150 new units are developed per annum, across four TODs, over the course of 20 years.[12] Since this growth is much slower than in our previous work, we do not assume any net movement from other areas of Hobart to the TODs; population densities elsewhere do not change and the roughly 1,500 net new migrants to Hobart each year (assumed in AEC Group, 2012) either move to the TODs, or replace people from Hobart who move from their existing homes to the TODs.

There are many assumptions associated with our approach above, and to provide some form of an external sense check of results, we compare our assumption of a 20-year development profile with the actual experience of Subiaco itself.[13] This is shown in Figure 5.

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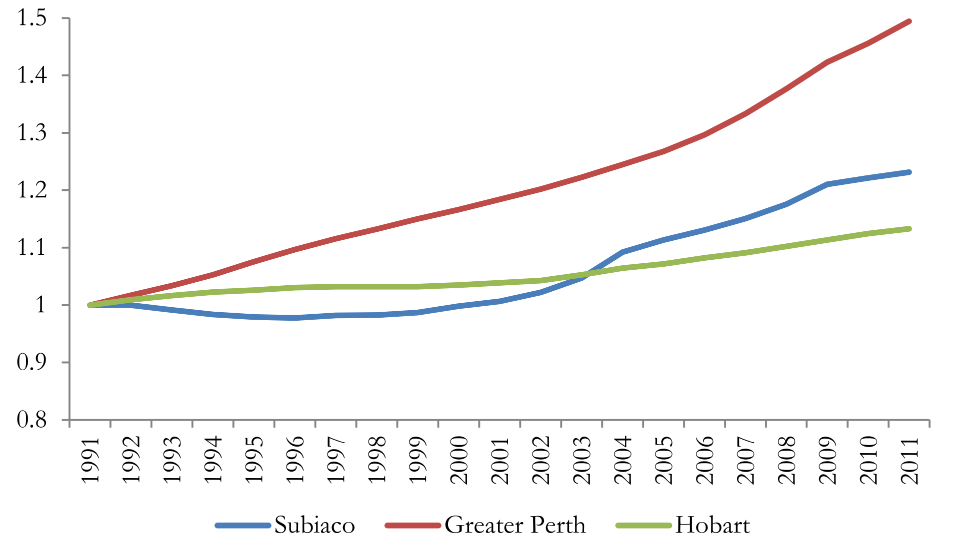
[11] We do not consider Macquarie Point, even though it is likely to develop as a TOD zone and is in our OOSMs, as its current population, according to the Census, is 19 people in 12 dwellings; numbers completely unrelated to planned developments in this area.

[12] Since where people live matters in the models, in cases where there are fewer than four OOSMS, we spread the 150 units across fewer TODs. Note also that, because the process takes 20 years, we need to run the model 20 times, comparing a base case in each year where the rising population is spread across Hobart as a whole with no LRV and a project case where the increases in population are more concentrated around each station.

[13] Glaeser & Gyourko (2005) provide some further evidence about the speed of urban renewal, and notes that the presence of existing houses can result in relatively slow changes to urban form, essentially because an existing house becomes less and less expensive as it depreciates and its reducing price can often compete strongly with the greater (and more expensive) amenity value of a new property. Although this work is in the US context, it does provide a useful background for thinking about the interaction between different types of housing stock, and understanding how this can lead to considerable "stickiness" in housing markets.

Figure 5 **The development of Subiaco in population figures**



Data source: ABS Cat No 3218.0

Subiaco station was moved underground in 1998, marking (roughly) the start of its development as a TOD. New housing units are still being developed in Subiaco at present, but from a population perspective, Figure 5 shows an increase in growth occurring during the decade from 1998, before growth rates level-off again in the last few years in the sample. Thus, one might conclude that the creation and maturation of Subiaco as a TOD (at least in a population sense) took a decade. Our assumptions above lead us to the conclusion that the four TODs in Hobart would take twice as long. However, the green and red lines in Figure 5 show that population grew much more quickly in Perth than in Hobart (Hobart growth rates in the AEC Group report over the next 20 years are projected to be roughly equivalent to the past decade). Thus, Subiaco was able to take advantage of much greater in-migration to WA, rather than relying on people moving from other suburbs in Perth. Since the TODs in Hobart do not have this advantage, 20 years of growth does not seem an unreasonable conclusion.

As a final point, it is worth re-iterating the importance of the TODs for the model. It is not for the economic activity or wider economic benefits which might be generated in these areas as they develop (see Section 5.4 for a detailed discussion of this). Rather, TODs are important for the numbers of people in them; as the numbers of people in the TODs grows, there are more people in each TOD to make the choice of LRV, bus or car for their commute, and thus to gain an increase in consumer surplus by virtue of the presence of the light rail system.

Use of annuity approach for BCA and residual values

Our original report had the costs of development as an annuity, and did not have a residual value for the railway; both "non-standard" from an IA perspective but, as AECOM point out in their review, neither resulting in major changes to our conclusions. We have changed both to reflect more standard practices.

Road decongestion from rail

As AECOM correctly point out, once some people make the decision to switch from road to rail, they will no longer be driving along the road, and thus congestion will be lessened. Since travel time savings are a key component of the benefits we calculate, this would mean that some people are induced back out of the LRV and into their cars. This, in turn, would induce a little more congestion, and so on until a new equilibrium is reached.

In principle, we could add a dynamic element to our model, which recalculates changes in consumer surplus until no more mode-switching occurs. However, this would be computationally intensive and time consuming and, unless the drop in congestion as the initial cohort move to rail is substantial, would not change the overall conclusions very much. For these reasons, we have chosen not to take these extra steps. However, this means that our predicted benefits will be slightly overstated, and our results should be interpreted with this lack of a dynamic effect in mind.[14]

Adaptations to IA format

This covers the non-quantifiable benefits and the sensitivity analysis. In both cases, we have now made changes in the relevant sections (see Sections 5.1 and 5.2) so that the assessment scale for non-quantifiable benefits and costs matches that used by IA, and so that the sensitivity analysis involves adjustment of the same parameters as suggested by AECOM, following the IA framework.

Decomposition of net benefits

AECOM suggested, correctly, that the standard IA approach is to show the contribution of each benefit type in the total; to show how much of the derived benefit comes from travel time savings, fuel cost savings and so on. If one is using a single representative consumer, facing a single set of costs, then this is relatively simple, as the proportions are the same for each person, and

[14] Note also Footnote 7, and the reasons for not including the change in consumer surplus for car drivers who remain on the road.

indeed the approach generally involves summing the benefits at a particular demand level.

Our model works differently. The elements of our cost functions (see discussion above and Appendix B) are the same as those which would be assessed in any IA assessment, and the values given to each element are also largely the same (where IA makes use of a "benchmark" value). However, each enters the model at the outset, and is used to derive the demand curve, which then feeds through into a calculation of consumer surplus and a change in consumer surplus. The end result, in terms of total benefits, is roughly the same, as AECOM point out.[15] However, because the relevant elements enter the model at the front end, we need to decompose our results into the various elements which go into their construction once our final aggregate results are obtained. The process by which we do this, along with the results, are described in Section 4.3.

3.3 PTEAM parameter changes

In this section, we provide an overview of key parameters in PTEAM, and note how they have changed since the previous iteration. Many of these changes have flowed from a meeting with key stakeholders in Hobart on February 7th 2013, where we sought advice on each of the relevant parameters. We are very grateful to participants at this workshop for lending their perspective to assist in our analysis.

A summary of the changes in the relevant parameters is provided in Table 5, which lists all of the key parameters in the model. Table 5 is then followed by a more detailed discussion of the reasons why certain changes have been made.

[15] The difference arises, at least in part, because the "standard" framework that AECOM uses is based around a linear demand curve, and the demand curves our model derives based on actual consumer behaviour are not quite linear.

Table 5 **Previous and current key parameters**

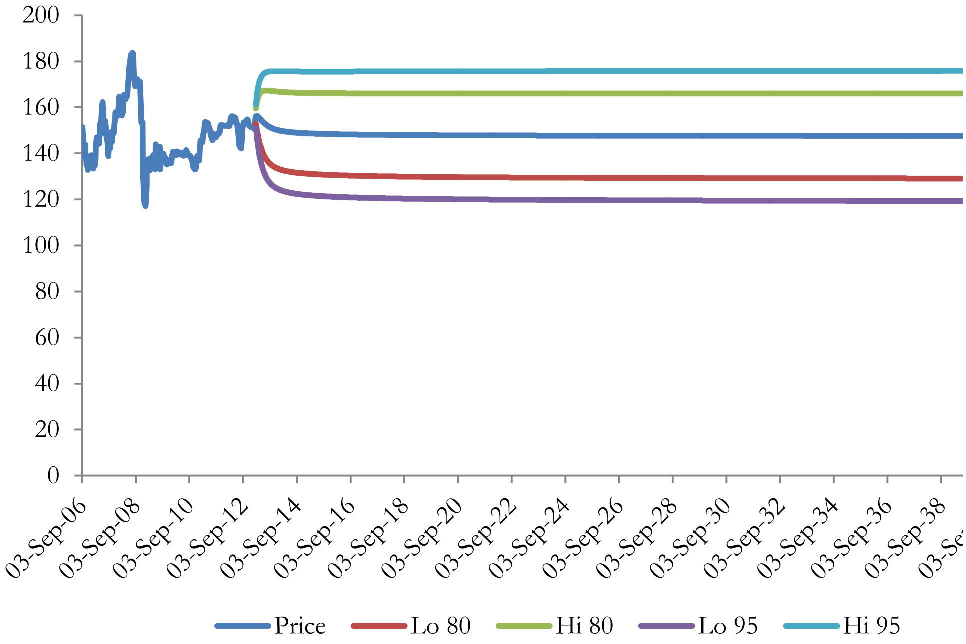
Input	Previous value	New value
Car speed	Inner 36-40 km/h, outer 53-57 km/h	Directed - Inner 40km/h, outer 80km/h with standard deviation of 10km/h. Non-directed – 90 (outer) and 60km/h (inner) with same standard deviation
Bus speed	Inner 30-60 km/h, outer 43-70 km/h	Directed - Inner 17km/h, outer 33km/h with standard deviation of 10km/h. Non-directed – 45 and 30km/h with same standard deviation
Feeder bus speed	n/a	Directed - Inner 22km/h, outer 33km/h with standard deviation of 10km/h. Non-directed – 45 and 30km/h with same standard deviation
LRV speed	36 km/h	30 to 35 km/h depending on the OOSM
Walk speed	5km/h	5 km/h
Value of travel time	60% av wage = $16.80/hr	$11.80/hr (ATC, 2006)
Fuel price	$1.20/l	Time series model
Fuel consumption	0.09l/km	0.1l/km
Ticket prices	$1.50	$3 for directed travel with standard deviation of 10 cents, $2 for non-directed travel with same standard deviation.
Parking costs	$3 per day per person	$8 per day per car
Parking availability	Assumed unrestricted	Assumed unrestricted
Pollution cost	$0.05/km	$0.05/km combined (ATC, 2006)
Road crash cost	$0.08/km	
Sparks effect	Triple mode share	20 per cent premium
Social exclusion	$19.30/hr	$0
Productive use of travel time	n/a	15 percent of trip for light rail, zero for other modes
Population proj.	0.66% pa (0.1% & 1.1%)	0.66% pa (0.1% & 1.1%) + TOD growth

Some of the changes in value are associated only with the passage of time and thus either new information coming to light, or inflation being applied to existing values. Population projections are now based on the more recent Census information which has come out in the interim between the previous report and our current work, and reflects the former aspect. Pollution and road crash costs represent changes associated with inflation. The remaining inputs represent more fundamental change, and as such, we provide a more detailed justification for each below.

Fuel price

In the previous version of PTEAM, the price of fuel was set to its level just prior to the study taking place; then the most recent data available. In this iteration, we have used six and a half years of weekly data on prices in Hobart, collected by DIER, to develop a time series model to project forward petrol prices through the course of the study.[16] The results of this modelling exercise are shown in Figure 6. In the context of Figure 6, note that the numbers are real (not including inflation); in nominal terms, fuel prices will roughly double over the course of the study period. For modelling purposes, we draw fuel price from the range between the "Hi 95" and "Lo 95" bands shown in Figure 6, set around a mean of 150 cpl; slightly higher than the average projected in Figure 6.

Figure 6 **Petroleum price changes**



Data source: DIER

Parking costs

In the previous report, parking costs were set at $3 per trip.[17] The actual price of an all-day parking ticket in the CBD (the destination of most commuter trips) is around $8 (based on information from DIER), but, the relatively low figure was justified based on the proportion of people who actually pay for parking, rather than parking for free in the Domain, or receiving free parking from their employers.

[16] The model is an ARIMA model created using the R forecasting package to optimally fit the data.

[17] For commuters; leisure travellers did not pay for parking, as free short-term parking is generally available throughout Hobart, including in the CBD.

At the stakeholder workshop on February 7th 2013, it was pointed out by several stakeholders that both parking provided by employers and parking in the Domain/inner city streets (on the fringe of the CBD) involve costs. In the case of employer-provided parking, the employee forgoes wages which might otherwise be paid. In the case of walking from the Domain/inner city streets, the commuter incurs a time cost associated with the relevant walk-leg of the trip.

In principle, it ought to be possible to value free parking and the average time spent walking from the Domain/inner city streets. However, it is arguably unnecessary to do so. Parking for commuters in the CBD is not congested on a daily basis, which means that people with employer-provided parking or choosing to walk into the CBD are not forced to do so for lack of available parking places in public car-parks. Instead, both are making trade-offs, and from this we can infer that they must value their time or the income foregone at less than or equal to the cost of parking. We therefore assume that all those who drive to the city incur an overall cost of $8 per car; in cash as a parking fee for those who park in public car-parks, in time for those who park at the Domain and in terms of lost income for those with employer-provided parking.

However, since parking a car accounts for two commuter trips (one to work and one home again), and since the average ridership per car is 1.2 people, the cost per person per trip of car parking is $3.30; about ten percent more than in the previous study.[18]

Sparks effect

In the previous report, we included a very large "sparks effect" which endeavoured to account for the fact that there is a preference for rail over other forms of public transport; all else being equal. We calibrated the effect based on the experience in Perth, where the replacement of bus services with a heavy railway in the southern corridor resulted in a tripling of the public transport mode share.

In its review, AECOM (2012) were highly sceptical of the size of the sparks effect and suggested that other public transport services improvements such as improvement in speed and service were responsible for the increase in patronage seen in Perth, rather than the mere fact that the service is provided by a train, rather than a bus. Moreover, in the stakeholder workshop, several stakeholders expressed concern at having such a large effect which could not

18 We note that the distinction that parking was per person per trip was not made with adequate clarity in the previous study, giving rise to confusion amongst some stakeholders.

be tied to particular causes; a point also made by AECOM. We would concur with this principled position (as we did in our report) and have introduced new elements into the model to try and quantify aspects of this sparks effect. However, we note that there are difficulties in tying down all contributing factors, and that IA has accepted "sparks effects" of around 20 per cent in the past. Thus, we have adopted a similar level for this analysis; increasing rail modal share by 20 percent above the figures in initial model runs to account for a "sparks effect".

Social exclusion

In the previous report, we endeavoured to quantify social exclusion, and include it directly into the benefit cost ratio, based on work undertaken in Melbourne (Currie et al, 2010). There was never a particularly neat "fit" between the work in Melbourne and the data which were available in Hobart; in particular, it was not possible to translate the definition of a socially excluded person in the Melbourne study to the Hobart context because of a lack of data in the Census on some of the characteristics.

At the stakeholder meeting in Hobart on February 7th, it was suggested that a lack of robustness around the social exclusion numbers in the benefit cost analysis might be injurious to the overall case, particular with IA. It was determined, therefore that a scan of previous submissions would be made to see if similar quantification had been undertaken in the past and, more importantly, how it had been viewed by IA. In the event of no such quantification or poor acceptance by IA, it was determined that the quantification of social exclusion ought to be dropped from the benefit cost analysis.

An assessment of past submissions and IA responses found no similar quantification of social exclusion in past submissions, and thus it was duly dropped. This does not mean, however that social exclusion is not important, nor that the proposed light rail system would have no influence on it. Social exclusion is important, and the impacts the light rail system is likely to have are addressed in Section 3.2 as a non-quantifiable benefit.

Travel utility and the productive use of travel time

Traditionally, in cost-benefit analysis, travel time is considered "dead time"; unused time that implies that any initiative which reduces travel time improves utility. However, there is an increasing body of literature which suggests that people do in fact, engage in productive use of their time whilst travelling and, moreover that activities differ across different modes of travel. This makes intuitive sense; if one switches a car trip for a train trip as a commuter, one can read work emails or documents on the train which could not be read in the car, thus extending one's working day. This ability is improving with advances in information and communications technology (ICT) and mobile technology.[19]

The point was made at the stakeholder meeting in Hobart of February 7th that the benefit cost assessment ought to take into consideration the fact that people are potentially better able to engage in productive activities in trains than in other modes of travel. We would concur with this observation, and hope that our attempts in this report to do so will spur further work in other infrastructure projects around Australia. Accordingly, we undertook a review of this growing literature to ascertain how to incorporate this element into the analysis. The result of this literature review is shown in Appendix C, which also explains how we reached our conclusions below.

There are two basic issues at play. The first is how to incorporate productive time into the analysis. We chose to do so by shortening the effective length of an LRV trip. Thus, if the operating models produced by Hyder (see Chapter 2) suggest a ten-minute journey from Glenorchy to Hobart, and the literature suggests 40 percent of people spend half their time on the LRV doing productive work, then this suggests the effective journey time, on average, is eight minutes (40% times 0.5 times ten minutes is two minutes). Thus, a person swapping from a 12 minute trip by car to work to the LRV saves four minutes of travel time in our model, rather than two minutes.

The second is to ensure that the productive time calculation reflects the marginal increase in use of productive time compared to what was possible using other modes. Thus, if the literature suggested the average person spent 20 percent of their time working on bus trips and 40 percent on LRV trips, then it would only be the 20 percentage point improvement that would be relevant for the person switching from bus to LRV, not the 40 percent figure for LRVs in general. Moreover, if all of the literature on productive use of travel is based on long train trips, one would need to be very careful in extrapolating to short trips, because the relevant proportions might not scale down exactly.

The second issue is particularly important in coming to firm conclusions about what the reduction ought to be in effective journey time for the average traveller. In the first instance, there is very little work in the literature of a cross-modal nature, meaning we have had to assume that productive work can only be done in LRVs and not in buses or cars. Secondly, although most of the literature focuses on trains, almost all of it focuses on longer trips, with

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[19] Although technology is a double-edged sword in this respect; with advances in automobile technology, a decade from now it may be possible to work in a car (more effectively than in a crowded LRV) that steers itself from home to work.

very little focussing on the ten to 15 minute range likely for the proposed LRS in Hobart. The small amount of work on shorter trips suggests there is a minimum trip time, below which no productive work is done, perhaps because there is not enough time to pull out the relevant "equipment".

Based on the literature (see Appendix C), we suggest that there could be a reduction in effective trip time of 15 percent for trips from Glenorchy to Hobart (and vice versa) compared to its clock-time. We cannot find support, however, for shorter journeys, originating or terminating at stops between these two.

A final point is worth making. The discussion above focuses on "productive time"; people doing work, essentially, on a train. It excludes the fact that people might do things on a train that give them direct utility, rather than monetary income, that they cannot do, or that are inferior, on other modes of transport. For example, a train might have wi-fi on it allowing for a person to watch a sports match that would be impossible to do on a bus or car. This is not explicitly included in our effective journey time reduction above. However, we do allow for a 20 percent "sparks effect" which increases the mode share of rail by 20 percent above the initial predictions of the model. AECOM (2012) suggested that any sparks effect might be due to amenity levels in the train, such as better seats or a smoother ride. However, one might also suggest that it is because of the greater range (or superior nature) of non-productive activities on a train relative to other modes, even though there is no empirical literature which shows what non-productive activities could account for a sparks effect of exactly 20 percent. The important point is that we do not believe that the model has somehow missed out these kinds of activities.

We have assumed that the research pertaining to train services is equally valid with respect to rail services provided by LRVs.

4 Benefit Cost Analysis

In this chapter, we present the core of the quantified part of our analysis; the benefit cost analysis and its results. The costs of each OOSM have been presented in Chapter 2, and the workings of the model which generates the benefits is shown in Chapter 3. The first section of this chapter shows the base case, and each of the project cases. The second provides the results, and the third provides a decomposition of the aggregate results into the various elements to allow comparison with other projects.

4.1 Base case and project case

The base case therefore involves a growing population, with the (real) values of other parameters remaining the same. In the base case, people in each of the SA1s are choosing between cars and buses for their trips. Each person makes two commuter trips per day (one to work and one home again), and two non-work trips including shopping, personal business and leisure trips.[20] The model calculates and sums the consumer surplus for Hobart as a whole each year within the context of these trips made using these modal choices.

The project case involves the introduction of a new mode of travel, the light rail, and the modification of the existing bus mode, to a series of feeder bus services that efficiently allow the bus and light rail system to interact. This is a once-off change made at the outset of the assessment period. There is an ongoing change (for 20 years) associated with the development of TODs around each of the (up to) four LRV stops on the route.[21] This has the effect of increasing the population by 210 people across the TODs each year, which results in more trips than would otherwise be the case. Note that these 210 people come from net migration. Thus, in the base case, we assume net migrants are allocated evenly across the city (in proportion to existing population numbers in each SA1), but in the project case, extra people are allocated to the SA1 areas nearest each rail stop which have been deemed to be TODs. In each year, the consumer surplus for all modes of travel is calculated, and is then added to the producer surplus.

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[20] This is based the travel survey for Hobart (DIER, 2010) that we used to calibrate our model, as well as discussions with DIER. It seems a little low, based on our experience elsewhere. However, any downward bias is unlikely to be substantial; there are only a small number of leisure trips made by public transport. Moreover, for those who switch, since they generally travel outside peak hours and avoid congestion, their per-trip savings are very low.

[21] We do not incorporate developments at Macquarie Point into our model

The producer surplus, proxied by the operating profit, is the difference between revenues and the sum of operating expenses, maintenance and depreciation.[22] Most of the passengers on the railway access it from a feeder-bus service, and thus we apportion the fare ($3 per person on average; we do not take out subsidies as these are presumed to be provided for other public policy reasons and to provide public benefits equal to their costs) 50/50 between the bus operator and the LRV operator. In a case where demand for each service depends upon the availability of the complementary service, this is the most likely commercial outcome. Changing this split would result in different benefit cost ratios, but would not alter our overall conclusions.

The sum of the producer surplus and consumer surplus each year is converted into a present value figure (using discount rates of four, seven and ten percent, as per IA requirement) and is the compared to the costs of establishing the railway.[23] This then provides a benefit cost ratio and a net benefit calculation. The results of this analysis are shown below.

4.2 Results of analysis for the four OOSMs

The results of our analysis are shown in Table 6.

Table 6 **Benefit cost analysis – core results**

OOSM 1	OOSM 1	OOSM 2	OOSM 3	OOSM 4
BCR				
4%	1.58	1.49	1.49	1.21
7%	1.12	1.06	1.06	0.86
10%	0.84	0.80	0.80	0.65
NPV				
4%	$44,326,000	$37,697,000	$37,755,000	$17,912,000
7%	$8,706,000	$4,370,000	$4,376,000	-$10,877,000
10%	-$10,635,000	-$13,648,000	-$13,680,000	-$26,052,000
IRR	8%	7%	8%	6%

The results appear clearly favourable to the proposed light rail system. OOSM 1 is the best of the options, but all of them have a benefit cost ratio which exceeds one. The results of our analysis are a function of the inputs and

22 Depreciation is over the full life of the asset. In some cases, this results in a smaller reduction each year than if we depreciated the entire asset base over the analytical period, and then left a residual value to reflect the fact that it could still be used. Adding a residual value in this context would involve double-counting, and thus we do not do so.

23 Note that the government-funded capital costs calculated by Hyder have been multiplied by 1.2 to cover their real resource cost. The 20 percent premium is at the low end of estimates of these deadweight losses (see KPMG, 2010).

assumptions that go into the analysis. Two of these are "non-standard", in that they reflect issues that are not raised in other benefit cost analyses in Australia, or the actual values are different from those accepted as "standard" by IA. These are the productive use of time on trains, and the transfer penalty.

Productive use of time on trains is something new, to our knowledge, in benefit cost analyses in Australia, and the empirical literature is not settled on the "appropriate" values (see Appendix C). However, even removing this from the model would not have significant effects on the results shown above.

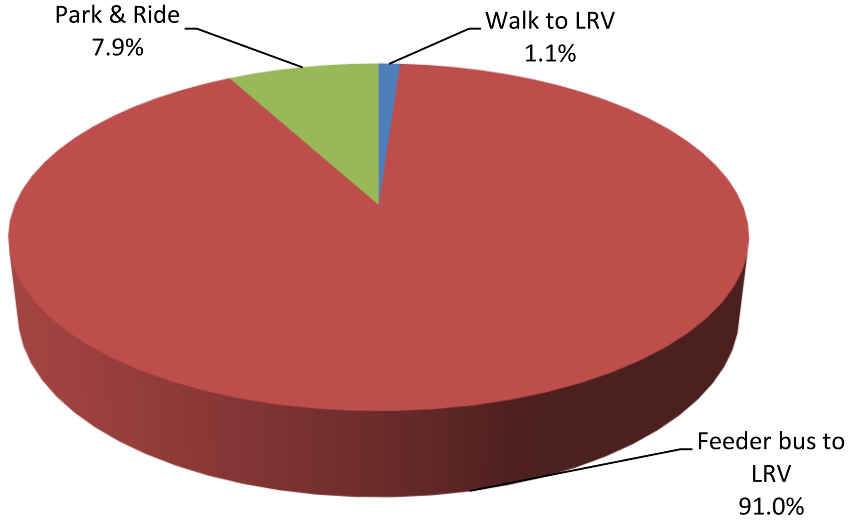
The "standard" transfer penalty (see ATC, 2006) is at least five minutes. As noted in Chapter 1, we believe this to be excessive, given the short trips involved, and the experience of cities like Perth with a well-functioning transfer system. However, IA is unlikely to accept a transfer penalty of zero. If the alternate transfer penalties was used, the resulting BCRs would be as shown in Table 7. Note that these results are all for OOSM 1, and that the other OOSMs would scale down accordingly.

Table 7 **Benefit cost analysis results – alternate transfer penalties**

	Five minutes	Two minutes	One minute	Zero minutes
BCR				
4%	0.00	0.67	1.11	1.58
7%	0.00	0.48	0.79	1.12
10%	0.00	0.36	0.59	0.84
NPV				
4%	-$83,453,527	-$25,251,088	$8,309,913	$44,326,000
7%	-$75,710,900	-$37,231,886	-$14,998,119	$8,706,000
10%	-$69,572,184	-$42,687,482	-$27,121,490	-$10,635,000
IRR	N/A	1%	5%	8%

The benefits are not created by the LRS alone. In fact, as shown in Figure 7 (for the average of scenarios which make up the demand curves), almost all of the passengers who use the LRS access it via a feeder-bus system. This is partly due to the very well-designed feeder-bus system, which matches the spatial location of demand well, but it is also a quirk of the assumption in the model that transfer penalties are zero. Since bus stops are pervasive across Hobart, this means that it is almost always quicker (in the model) to get on a bus to access an LRV stop rather than by car, bicycle or foot. In reality, people will have non-zero transfer penalties, which will mean more walk-on traffic than our model suggests.

Figure 7 **Composition of light rail passengers**

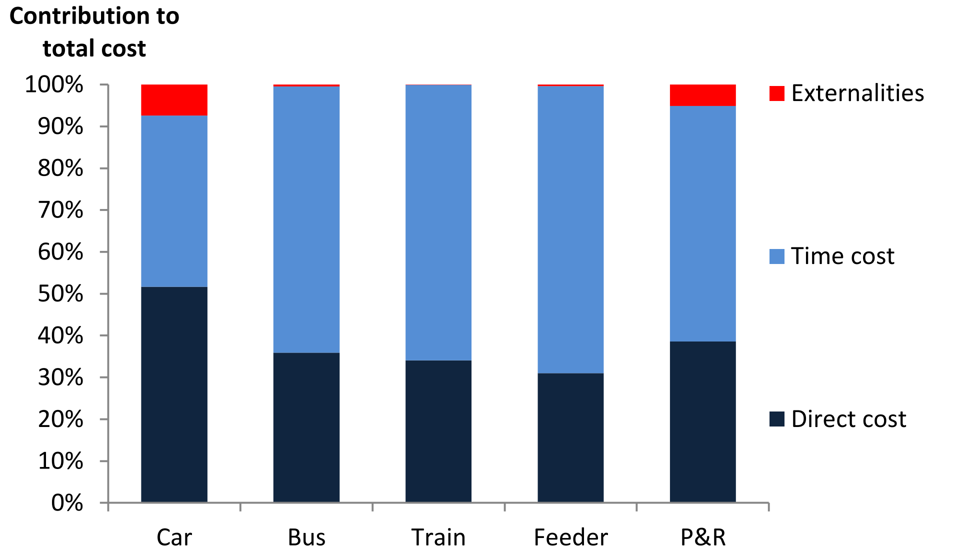


4.3 Decomposing the results

In our original report, we presented the overall benefit cost ratios and net benefits, but did not outline the contribution of each aspect of the relevant benefits to the final results; the percentage due to travel-time savings, to pollution reduction and so on. AECOM (2012) noted that, although there was no intrinsic problem with our approach, it did make it difficult to compare the results with other Infrastructure Australia submissions to understand, for example, whether travel time savings were much more important in this study compared to other submissions.

For this reason, in this report, we decompose our results to show the proportion of the benefits that can be attributed to each of the elements which go into their calculation; how much is associated with travel time costs, pollution reduction and so on. The results are shown in Figure 8, where direct costs are parking, fuel and maintenance for cars and tickets for public transport, and externalities cover pollution and accidents.

Figure 8 **Contribution to travel costs**



For cars, roughly half the costs are direct, and roughly half the costs are time costs, whereas the other modes (all of which involve some degree of public transport) have a higher share of time cost. This has an impact in the sensitivity analysis where we increase the value of time (see Chapter 6).

There is a direct link between the shares of cost elements and the benefits, in that, where people shift from car to a public transport mode, they shift their mix of time and direct costs. By way of an example, after the introduction of the rail network, around 70 per cent or rail users switch from cars and 30 per cent from busses. If the average car and bus costs stay the same then this means that about 30 per cent of the benefits come from time saving, 10 per cent from a reduction in externalities and 60 per cent from direct costs savings.

5 Non quantified Costs and Benefits

In this section, we provide an overview of non-quantifiable costs and benefits associated with the proposed light rail project. It is important to note at the outset that, just because a particular cost or benefit does not have a dollar-value associated with it, this does not necessarily mean it is unimportant. In fact, in many instances, economics is poorly-equipped to assess a cost or a benefit, and turning the analysis into a dollar figure often misses key aspects of the benefit.

For example, although it is possible to robustly turn a health outcome into a dollar figure using Quality of Life Years or Disability Life Years, or to estimate the increase in income that accrues to a person with disabilities by being able to access employment, economics has little that is valuable to say about the improvement in self-worth that person feels by being able to contribute more fully to society.

Societies make decisions outside narrow economic grounds all the time; the protection of heritage buildings, the mandating of access for people with disabilities, the construction and preservation of parks and so on. In each case, a judgement of the "welfare effect" is being made, but it is rarely "dollarized"; moreover, when it is, the numbers are often not very robust. There is no intrinsic problem in society ignoring economic analyses completely when making investments, provided the decision is being made in full knowledge of the costs involved (so that those in the society can trade-off the dollars for the unquantified benefits) and provided that those funding the investment are adequately represented in the decision-making process. It is for this reason that we would urge stakeholders examining this report not to base decisions solely on the chapters with dollars in them.

One final point is worth making. In assessing the non-quantified costs and benefits, we make use of the "standard" matrix used by Infrastructure Australia, shown in Table 8. However, it must be remembered that, although the categories may appear objective, any assessment of non-quantified benefits and costs brings in a degree of subjectivity; by definition, something that cannot be quantified can only be assessed in a subjective manner. In our assessment below, we have endeavoured to capture costs and benefits that various stakeholders have suggested are important, and to reflect the views of those making such statements. However, we have not necessarily reflected a "consensus view" for each cost and benefit, but rather made our own assessments, based upon the facts as outlined in each case. In so doing, by virtue of the nature of the costs and benefits themselves, we have used our judgement. Our findings should be interpreted, and debated within the community as appropriate, in this light.

In short, if the results of the cost benefit analysis (based upon objective information) suggest not proceeding on the basis of low net benefits, then the result can be challenged with reference to the underlying methodology, or by pointing out errors in particular calculations. However, our conclusions in respect of non-quantifiable costs and benefits can be challenged by offering a different viewpoint. Moreover, the challenge can and should be sustained within the arena of public debate over the light rail project by convincing others in the community of a different viewpoint from that outlined below.

Table 8 **Infrastructure Australia typology of non-quantifiable costs and benefits**

Rating level	Description
Highly beneficial	Major positive impacts resulting in substantial and long-term improvements or enhancements of the existing environment.
Moderately beneficial	Moderate positive impact, possibly of short, medium or longer-term duration. Positive outcome may be in terms of new opportunities or outcomes which enhance or improve on current conditions.
Slightly beneficial	Minimal positive impact, possibly only lasting over the short-term. May be confined to a limited area.;
Neutral	Neutral—no discernible or predicted positive or negative impact
Slightly detrimental	Minimal negative impact, probably short-term, able to be managed or mitigated, and will not cause substantial detrimental effects. May be confined to a small area.
Moderately detrimental	Moderate negative impact. Impacts may be short, medium or long-term and impacts will most likely respond to management actions.
Highly detrimental	Major negative impacts with serious, long-term and possibly irreversible effects leading to serious damage, degradation or deterioration of the physical, economic or social environment. Requires a major re-scope of concept, design, location, justification, or requires major commitment to extensive management strategies to mitigate the effect.

5.1 Non-quantifiable costs

In this section, we explore the non-quantifiable costs associated with the proposed LRS. In the main, they are not associated with the LRS directly; estimates of its construction and operating costs are subject to uncertainty, but are, conceptually at least, relatively clear. Rather, they are generally associated with costs that may be imposed upon the community from the railway being operational.

Traffic delays during construction

The existing railway line will require considerable work to bring it up to a standard suitable for use by passenger rail vehicles. There are also LRV stops, passing loops, maintenance facilities and other associated support infrastructure which require construction. Overall, the construction process is likely to take two years. During this time, there is the potential for delays to road users, as well as reduced amenity for residents around what will become a long thin construction site.

However, the fact that construction could become a major inconvenience, albeit for a short time, does not necessarily mean that it would. Adroit planning can reduce impacts considerably; undertaking noisy construction work during daylight hours when residents are less likely to be at home, and doing work that requires road closure at night when it impacts on traffic least. We would anticipate that such adroit planning would accompany the development of this LRS, and as such would consider this cost to be slightly detrimental.

Traffic delays during operation

One particularly pertinent cost which has not been included is the cost of congestion on the roads caused by the light rail system. The rail line intersects with 11 roads, six of which are important parts of the road system. None of these are grade separated with the exception of the bridge across Risdon Road and the underpasses under the Brooker and Tasman Bridges and would thus be controlled with signals. At present, there are few issues, because there is only limited activity on the rail corridor. However, once the light rail service commences, the service frequency will mean that each intersection is closed at least twice every 15 minutes to allow the light rail vehicle to safely cross the intersection.

In principle, this is a cost that can readily be quantified using a standard traffic model of the city in question to examine how periodic stops influence how traffic flows through the system as a whole. Hobart, however, has no such model of its traffic system outside the Hobart CBD which can be readily applied in this instance, and thus we have not quantified this particular cost.

We would suggest that, at some stage of the planning process for the light rail, traffic modelling be undertaken. In particular, if the extra travel time for road users from stopping at signalised rail crossings is greater than the travel time saved for those actually in the LRVs, then the system creates a net dis-benefit to the community as a whole. We do not believe this would be the outcome from such a traffic model, necessarily, but until the question is tested, the benefit cost analysis is incomplete. For this reason, we would suggest that this particular cost be considered highly detrimental; if only to motivate answering the traffic question with more clarity such that adjustments to the calculated BCA can be made. In other words, the conclusion of "highly detrimental" is not a judgement on the likely scale of the problem, but rather on the consequences of not knowing the answer to this particular question.

Impacts on bus services

One of the factors which led to the closure of rail services in Hobart in the 1970s was low patronage caused by competition from buses. To the extent that the railway provides a superior alternative to existing bus services, the railway may now do the same thing in reverse, and have an impact on Metro; although we understand that the route between Glenorchy and Hobart especially along the main road is one of Metro's most viable routes, although it performs a different role, as a "conveyor belt" picking up people and dropping them at stops all along the main road, rather than just as a shuttle between Hobart and Glenorchy. It is also distant from the rail corridor for the majority of its length south of Moonah through New Town and North Hobart.

Competition between services is not a problem from a social welfare perspective; if customers choose the light rail system over a competing bus service because they prefer it, then this increases social welfare. It is also not necessarily the case that competition will be the outcome,[24] nor that bus patronage will decrease. Our model of the railway includes changes to the bus network to introduce feeder bus services (something which has been highly successful in Perth), and this actually results in more people riding on buses

The issue arises if the degree of competition from the LRS on the bus system causes Metro to lose some of its economies of scale, and thus has an influence on its ability to provide services throughout the wider Hobart metropolitan area without additional subsidies. This might occur if, for example, relatively well-patronised routes between Hobart and Glenorchy are currently cross-subsidising less well-patronised routes elsewhere in the city, and these well-patronised routes are replaced by a rail service. This has not been tested in detail by examining Metro's accounts.

However, the feeder bus system developed for each of the OOSMs is developed by removing the least viable of the current routes and diverting resources within buses to feeder bus services that would complement the light rail system, and indeed see a large increase in patronage because of it. This would suggest that any adverse impact on Metro from the LRS would be slightly detrimental. However, we make this statement without having had the opportunity for detailed discussions with Metro on how costs are allocated across services and what kinds of cross-subsidisation occurs (if any), and we

[24] The eventual ownership of the railway has not yet been considered. If Metro runs the buses and the LRS, it would have incentive to maximise the benefits of this joint profit, and would therefore remove competing bus routes of its own volition, and ensure that feeder bus services mesh. Ownership by different companies does not preclude co-ordination (one of the authors has personal experience of this from living in Japan and commuting daily on well-integrated private and public railway lines), but as the historical experience of Hobart shows, it can make it more difficult.

would suggest, if only because of the history of "ruinous" transport competition in Hobart, that DIER hold such discussions with Metro as part of the planning process of the light rail system.

Safety at Mawson Place

At present, Mawson Place is a pedestrianized environment, and the planned LRS would see LRVs running through this pedestrianized zone. This potentially represents a danger for pedestrians, who may not be watching out for an LRV travelling through their midst.

To understand the scale of this cost, consider the following:

- A study undertaken by Alfred Hospital doctors in Victoria found that in the eight years to 2010, there were 15 deaths and 107 major trauma cases in Victorian hospitals which could be associated with tram accidents.[25]
- Data from Public Transport Victoria shows 1.415 billion passenger trips on trams in Melbourne during this time.[26] If we assume (overstating the cost in doing so) that major trauma and death have the same cost to society, and ought to be treated together, this means there were roughly 0.086 deaths and major trauma cases per million tram trips in Victoria.
- The Office of Best Practice Regulation suggests that the value of a statistical life in Australia is $3.5 million in 2007 dollars, or roughly $4 million today.[27] This means that the cost to society (with the caveat noted above on treating major trauma and death together) in terms of death and trauma for Melbourne's trams is $344.85 per million trips.

The modelling undertaken as part of the benefit cost analysis suggests that around six million trips per annum will be undertaken on the proposed light rail system. This suggests an annual accident cost of $2,100.[28] However, we have not included this cost in the benefit cost analysis because we do not consider it to be sufficiently robust. In the first instance, death and major trauma are not the same, as noted above. More importantly however, Melbourne's trams mix with traffic and pedestrians in a much denser urban environment over more than 200km. In Hobart, pedestrians and the light rail system would mix over a distance of a few hundred metres, meaning the figures above calculated on a per passenger trip basis likely significantly

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[25] See www.heraldsun.com.au/news/victoria/research-finds-accident-rise-put-down-to-silence-of-melbourne-trams/story-e6frf7kx-1225909057262 for the citation of this research. The newspaper article is a little too vague on sources to source the original study.

[26] See http://ptv.vic.gov.au/assets/PDFs/Random/Market-Analysis-Patronage-Long-Run-Series-2012.pdf.

[27] See http://www.finance.gov.au/obpr/cost-benefit-analysis.html.

[28] The reduction in accident risk from fewer car trips is much greater than this and is included in the benefit cost analysis results.

overstate the relevant risk. For this reason, we consider this cost to be slightly detrimental, from the perspective of IA's categorisations.

Opportunity cost of the land

If the land is not used to develop a LRS, it could potentially be used for other purposes that provide some socio-economic value. However, in reality, the long, thin piece of land has limited alternative uses. It could be sold off piecemeal to the abutting land-holders to increase the size of their plots. However, in many places, there are no adjacent landholders.[29] Moreover, the value of the land net of the costs of any clean-up costs associated with removing track and ballast after more than a century of railway traffic are likely to be small. Finally, the sale of the land, even in part, would remove any ability for Hobart to utilise the transport corridor in the future, limiting future transport planning.

The other alternative is to make use of the land for a different transport mode. Originally, the track was double-tracked through the reserve, and one half of this has already been turned into a cycleway. The cycleway is very popular due to a lack of flat land for cycling in Hobart, but it is unclear whether an additional cycleway would be of significant additional value, except insofar as it preserves the land for a future transport corridor. Moreover, there would likely be considerable cost in removing rail and ballast to construct the new cycleway.

There have been proposals in the past for a busway along the existing rail route from Hobart to Claremont (Pitt & Sherry, 2009). This is slightly longer than the proposed rail route, but the projected cost was $115 million; more than the light rail system.[30] At the same time, although it would be more flexible than the rail system (as all buses could use the busway, whereas the rail solution requires a transfer from feeder buses), it would miss the "sparks effect" associated with rail being more attractive than buses. A more expensive way of providing what may be a less attractive service does not really represent an opportunity cost for the land.

For the reasons discussed above, we conclude that any opportunity costs associated with the land to be used by the light rail system are likely to be neutral from the IA perspective.

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[29] In some places there are roads either side of the reserve, and for a long stretch, the line skirts a parkland.

[30] In our original work two years ago, some stakeholders disputed this cost figure indicating it was too high.

Impact on existing users of the rail line

At present, the line is used by heritage and freight trains. The former make use of the line very rarely (mostly on special occasions) and the latter will cease using the line in the near future, after TasRail vacates its current site on Macquarie Point for the Brighton Intermodal Hub. Since the proposed option is for standard, rather than narrow gauge (to reduce costs of rolling stock; see Chapter 2), neither the heritage trains nor the freight trains will be able to operate on the proposed line without gauge conversion. There is no rationale for freight trains to utilise the line, as the re-development of Macquarie Point will mean they have nowhere to go on the line itself. They thus suffer no adverse consequences from the proposed LRS.

Heritage trains, which run only sporadically in any event, may need to undergo gauge conversion if they are to continue to run southward towards Hobart. This is not a large cost, given the small number of vehicles, and, potentially, the use of volunteer labour (say from the Tasmanian Transport Museum, who already do rail maintenance on these vehicles). For this reason, we suggest that the impact is slightly detrimental.

5.2 Non-quantifiable benefits

In this section, we provide an overview of non-quantifiable benefits. Some of these are categorised according to the categories outlined by IA (2012, p21) and some are benefits suggested by stakeholders; both to us directly and through the media in Hobart. We have examined each benefit, though we do not necessarily concur in each case that the benefit is real.

Social exclusion and access

See broader discussion on equity and distributional concerns in Section 5.3. Although better access improves social exclusion and access and is thus an important policy goal, the counterfactual in this instance is not a lack of access, but rather a bus system which provides (or could provide with some relatively low-cost modification; the next best option is not very different from the light rail system in terms of access) access at comparable levels of reliability to a light rail system. It may be the case that people are not using buses because they do not like to use them, but unless this preference is based upon some pervading issue such as public safety (which it does not appear to be), we do not consider that preference alone ought to be a prevailing concern in transport policymaking that has as its desire the improvement of social inclusion and access; certainly making it a prevailing concern has the potential to significantly increase the cost of public transport. For this reason, we consider the marginal improvements in access to represent only a slight benefit. However, we fully recognise that others may consider (and may make cogent arguments supporting their position) that preferences ought to be given a greater weight than we have given them.

Heritage and cultural values

Assessing the heritage and cultural value of the LRS is problematic, due to lack of firm data. Whenever the system is mentioned in the popular press, there are some comments which are negative, and in the initial investigation two years ago, there were some concerns about overhead catenary wires in Mawson Place.

However, there is bi-partisan political support for the LRS, and vocal lobbying from numerous groups for its development. Moreover, as the submission from the Greens candidate for Denison, Anna Reynolds to the AECOM (2012) review shows (with its long list of comparably-sized cities around the world that have light rail systems) that there is a viewpoint in the community that the light rail system will show that Hobart has "arrived" as a city; a sentiment that has been expressed by other stakeholders.

Overall, the public sentiment towards the LRS, as it has been expressed to us by stakeholders is positive, this much is clear. However, most of the support for the railway is couched in terms of its other benefits, not in terms of culture and heritage. For this reason, we have judged that its cultural and heritage value is only slightly beneficial; it has many other benefits which make it worthwhile.

As a final point, it ought to be noted that the proposed LRS will not cause any harm to existing areas of cultural heritage. The track already exists, and the LRS would not thus require any destruction of existing assets for the service to be developed.

Health benefits from active transport

To the extent that the LRS shifts people from their cars to more active forms of transport, this may result in health benefits to the community at large. In our model, car trips involve no walking leg to access the car, while bus trips involve a walking leg to the bus stop, but it is assumed that the bus rider alights from the bus at a stop very close to her destination. An LRS patron has a walk to the rail service or feeder-bus, and then is assumed to walk to her destination.

If we allow for ten minutes more walking for each person switching from bus or car to the light rail service, which is slightly more than is the case for someone switching from car to light rail service and about five minutes too much for those switching from bus (who only add the destination walk), then this gives us a rough basis from which to assess health benefits.

The authors of this report are economists, not health professionals. However, a brief web-scan of the benefits of walking suggest that benefits begin to emerge after 30 minutes of walking per day; even if it is in smaller increments.[31] Thus ten minutes of additional walking, particularly when taken in two five-minute bursts, would not alone appear to have appreciable health benefits. However, it could contribute to some people reaching their target of 30 minutes of walking per day, and others beginning to think more carefully about healthy lifestyles. For these reasons, we consider the benefit to be slightly beneficial.

Improvements in social capital

Improvements in human capital could occur if the LRS allowed more people to access more and better training and education activities. These benefits would be important if the system were connecting people who previously lacked connection, thus allowing them to access services that were previously unavailable. However, in the case of the proposed light rail, it is unlikely to promote any new access as it does not serve any areas that are not already served by bus. Instead, what it provides is an improvement in trip times for its passengers. There may be some very small coterie of people who are unable to access a bus (say due to a particular disability which means that their wheelchair cannot fit into a kneeling bus but could fit into a light rail vehicle). However, given the marginal impacts of the LRS in terms of access, improvements to human capital associated with it are likely to be slightly beneficial.

Tourism benefits

One group of potential rail passengers who have not been included in our modelling are tourists, who might utilise LRVs to move around Hobart. Note in this context that we are talking about visitors to Hobart, rather than Hobart residents travelling to certain destinations (the Royal Hobart Showgrounds, the Derwent Entertainment Centre and Elwick Racecourse, for example for leisure purposes; these are included in our non-directed model). Tourism Tasmania tracks visits to 27 different attractions around Tasmania, and the top-ten attractions are:[32]

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[31] See www.betterhealth.vic.gov.au/bhcv2/bhcarticles.nsf/pages/walking_for_good_health?open, www.juststartwalking.com.au/home/why-walk www.health.harvard.edu/newsletters/Harvard_Mens_Health_Watch/2009/August/Walking-Your-steps-to-health and www.mayoclinic.com/health/walking/HQ01612 for several examples.

[32] The survey asks about visits to 27 different attractions (see www.tourismtasmania.com.au/__data/assets/pdf_file/0005/49343/tvs_questions_2011_1

- The Salamanca Market (40 percent of visitors).
- MONA (25 percent of visitors).
- Port Arthur (23 percent of visitors).
- Mount Wellington (21 percent of visitors).
- Cataract Gorge (19 percent of visitors).
- Cradle Mountain (20 percent of visitors).
- Freycinet National Park (18 percent of visitors).
- Blowhole/Tasman Arch (15 percent of visitors).
- Royal Tasmanian Botanical Gardens (12 percent of visitors).
- Lake St Clair/Derwent Bridge (10 percent of visitors).

Most of these attractions are outside Hobart itself, and thus inaccessible via the LRS or its feeder buses. The Salamanca market is in the centre of the city (as are numerous other attractions), but since most hotels are also in the centre of the city, tourists would be unlikely to use the proposed light rail to access them.

The Museum of Old and New Art (MONA), one of the most attractive destinations in Hobart, is roughly 4.5km north (down Elwick Road and up the Brooker Hwy) from the LRS terminus at Glenorchy. MONA is currently serviced by an existing ferry service which leaves from Constitution Dock with a very scenic ride up the river, and indeed was designed to be approached from the water by such a ferry service.[33] MONA also runs a specialised bus service the MONA ROMA which travels express from Hobart directly to MONA. Metro has also introduced a special MONA timetable, which information about services from the Hobart City Interchange in Elizabeth Street and takes roughly 27 minutes to travel to a stop outside the gates of MONA.[34]

The ferry service may not be sufficiently frequent or timely for all visitors, and visitors from interstate or overseas may not be willing to make use of bus services out of concern at getting off at the wrong stop (although the Metro Access Guide provides very clear information). The MONA ROMA offers service directly to MONA. There may be some passengers who want to take the LRV for the experience, even if this means transferring to a bus at

2.pdf). Some of the remainder are in Central Hobart, but the rest are outside Greater Hobart, and inaccessible by the proposed light railway. Note that the percentages above are taken from a bar chart produced by Tourism Tasmania, and are approximations.

33 See http://www.mona.net.au/visit/getting-here/; the site also offers other options including seaplane and helicopter. Note also that the popularity of the ferry service has resulted in the construction of a larger ferry (www.themercury.com.au/article/2012/12/06/367765_tasmania-news.html)

34 See www.metrotas.com.au/uploads/file/12548_Metro_TAG_MONA_NOV12_web.pdf. Note that those using the Metro bus need to walk up a hill to MONA itself.

Glenorchy stop. However, it seems unlikely that the LRV service would be a major drawcard for visitors to MONA, given that it does not actually go to MONA, and (with the shuttle bus) may be slower than even the existing bus services; although departure times would be more frequent. Tourists with time are most likely to catch the ferry, and those short of time are more likely to either use a private (or hire) car, a taxi than to catch an LRV. For these reasons, it seems unlikely that the market for rail visitors to MONA would be substantial.[35]

The Royal Tasmanian Botanical Gardens are directly on the rail line. At present, none of the OOSMs have a stop at the Gardens, but it would be possible to install a "special events" stop at the Gardens for this tourist trade, and there has been some discussion in Hobart of using historic trams for the service. Any such service, however, would need to be managed within the timetabling of existing LRV services to ensure that provision of services for tourists does not detract from services being provided to commuters.

Although visitor numbers are available, what is not clear is the cross-elasticity of demand between modes for tourists, which would indicate how many tourists might switch modes if a new mode were available. Moreover, the benefit which is generated is not the total utility for the trip, but rather the net increase in utility compared with other means of getting to the Gardens.[36] This may be relatively small. If the tourist tram is run by government at a loss, these additional tourists may in fact reduce the overall net benefits of the LRS.

One aspect of tourism benefits which we have not explored is the potential benefits from more tourists coming to Hobart because of the LRS; the light rail acting as an attractor in the same way that MONA does. Though we have no doubt that some tourists will come to Hobart specifically because of the light rail, this coterie of tourists is likely to be very small.

Overall, our conclusions in relation to tourism benefits is that they are likely to be slightly beneficial; particularly when seen from the perspective of how much additional utility the light rail system provides for tourists relative to other transport modes.

[35] This may change in future if the line extends past Glenorchy, and indeed there is scope for the operators of MONA to fund expansion of the service past Glenorchy to operate a "MONA express" train that provides the same kind of high-quality service as existing ferries. This would be a commercial decision for the operators of MONA.

[36] The same is true of any tourists using the light rail to get to MONA.

Business travellers

Although we include commuters in our sample (ie – people travelling from home to work) we do not include business to business travellers who travel during work hours. The per-hour value of time for these travellers is particularly high, because it is essentially their total cost of employment. Thus, if travel time is viewed as "dead-time" (see discussion in Appendix C), then savings in travel time would be more substantial for each business user than for each commuter.

In principle, it is relatively simple to incorporate business travellers into our model framework; they are simply another group of travellers, with the same travel choice set but with different values of travel time. The constraint is not conceptual, but rather data-driven; there simply is no reliable information on how many business trips there are in Hobart between the city centre and Glenorchy (or indeed, throughout the city as a whole). For this reason, we do not have the basic inputs needed to undertake the analysis.

Although this means that we have likely under-estimated the total benefits, we would suggest that this benefit be categorised as slightly beneficial based on the IA categories in Table 8 above. This is because congestion is largely focussed during peak hours in Hobart, and during the inter-peak period (when most business to business travel would occur) the LRVs are in fact slower than other modes (particularly cars), particularly if both the origin and destination of travel are not located close to the relevant LRV stops.

Savings for other infrastructure

One potential benefit occurs not with the LRS itself, but with a denser urban form which might emerge around a system by, for example, the development of TODs. Development benefits associated with TODs are discussed in Section 5.4; here we focus particularly on the impacts associated with infrastructure serving these denser urban areas. As a general rule, there are economies of scale in the provision of infrastructure, meaning the cost of serving a given number of people in, say, a square kilometre of urban space rises less than linearly with the number of people inhabiting that space. In a series of papers (See, for example, Bettencourt et al, 2007) a group of physicists examining scale economies across cities in the US and Europe of different sizes find a surprising degree of regularity in terms of economies of scale. Whether one is talking about telephone line, roads, service stations or railways, it appears that a doubling of population requires only an 85 per cent increase in hard infrastructure to serve it. Thus, it would appear that there could be significant gains from increasing density, by saving on the provision of other infrastructure.

There are two counter-points which need to be made. The first is that this benefit is associated with an increase in density, not the construction of a light rail system. Although an urban light rail system can be a strong catalyst for creating denser urban living environments, it is not the only way in which this could occur. For example, a bus-way might also serve as the core of a dense urban form.[37] Moreover, from the IA perspective, such indirect benefits are not generally considered as part of a cost benefit assessment.

The second issue is that the 85 per cent figure is an "all else being equal" figure; if a planner had a blank slate and could choose between a dispersed and a dense urban form, the dense urban form would be less expensive for infrastructure. However, in this instance, there is not a blank slate. There is existing infrastructure in place for water, telecommunications, power, sewerage and other amenities in the relevant regions through which the light rail system would run. If density increases, existing infrastructure may need to be replaced, if it is no longer large enough to serve a denser population.[38] In cases where the infrastructure is underground, this means it will need to be dug up.

Any assessment of the benefits associated with infrastructure cost savings would need to factor in the costs associated with replacing existing infrastructure. This may result in a net cost, not a net benefit. This is a benefit which is quantifiable in principle. However, it is beyond the scope of this study to undertake a full audit of all of the infrastructure in the affected region. Moreover, even if the relevant data were easily available, the first issue of the indirect link between the LRS and the infrastructure savings is important. For this reason, we adopt a middle ground, and suggest that the relevant benefit is neutral, based on the IA categories above.

Employment effects

The LRS will provide a small stimulus for employment during its construction, and a smaller number of operational jobs. However, the main aspect of the benefit of the system from an employment perspective is its ability to connect people to jobs. We discuss this in more detail in Section 5.3 below. However, given the conclusions of this discussion about the marginal benefits of light rail over existing options for transport, we consider this to be slightly beneficial.

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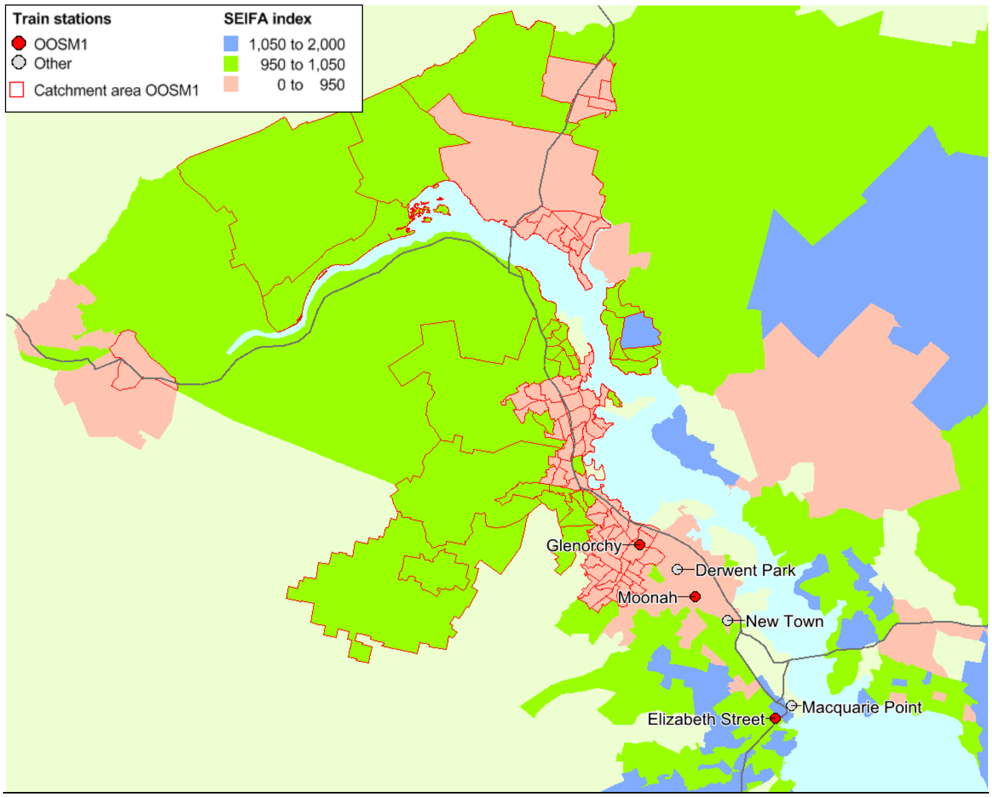
[37] Buses can carry fewer people than LRVs, and thus the limits of density in an area served by buses might be lower than that served by trains. Alternatively, the greater attractiveness of LRVs to buses might make a train-based transit-oriented development zone more successful than one based around buses. In both cases, it is the marginal effect of trains over buses (or whatever is the next best alternative) that is important, not the total effect.

[38] Trunk lines outside the immediate area may also need to be increased in size, to service the larger number of people in the region.

5.3 Equity and distribution considerations

In this section, we discuss equity and distributional aspects associated with the light rail system. This has been an issue of considerable importance in the minds of many of the members of the public commenting on the light rail system. For example, David Walsh, the owner of MONA has supported the LRS proposal as a matter of "social justice"; connecting areas where unemployment rates are very high to economic opportunity elsewhere.[39] It is most certainly true that the areas of Hobart primarily served by the LRS and its feeder-bus services are relatively disadvantaged, as evinced by Figure 9, which highlights socio-economic disadvantage.

Figure 9 **Socio-economic disadvantage in Hobart**



Note: A lower score indicates that an area is relatively disadvantaged compared to an area with a higher score. The SA1 index scores have be standardised to have a mean of 1000 and a standard deviation of 100 across all SA1s in Australia.

Data source: ABS Cat No 2033.0.55.001

It is true that providing access to employment, and to other aspects of society is a very important task for PT. It is also true that this importance increases when the people for whom access is being provided are those from lower socio-economic backgrounds. From this perspective, a light rail service

[39] See www.themercury.com.au/article/2013/02/18/372655_editorial.html

through an area such as the study area above might be seen as having important equity and distributional considerations.

However, as is always the case, the light rail service needs to be assessed against a counterfactual, and the counterfactual in this case is that people in the regions outlined above have access to bus services that provides social and employment access to precisely the same destinations as the rail service will provide. Moreover, the frequency of the bus services in the immediate area are not vastly worse, in terms of frequency, for most users than the LRS.[40] It is certainly a matter of social justice to provide good PT services to people who have none, but what the LRS is actually doing is providing a new service style (which might be preferred; LRVs are generally a preferred means of public transport to buses) to those with existing services that they can already utilise if they so choose. This is a much smaller distributional and equity consideration.

The issue is shown in sharp relief when considering employment aspects, highlighted in the *Mercury* article cited above. If there is a major benefit for unemployed people (with access to buses) from having a rail service to access jobs, what this implies is that there are significant numbers of people in the affected areas who are unwilling (rather than unable; people who claim unemployment benefits are different from those claiming disability benefits) to make use of the existing bus service to access employment. This seems highly unlikely to be true. In fact, we suspect that unemployed people in the affected regions are making use of any form of transport they can to access employment. In the unlikely event that they are not, we suspect there are far more cost effective measures government could implement to improve incentives for these people to access jobs via public transport than building a light rail system.

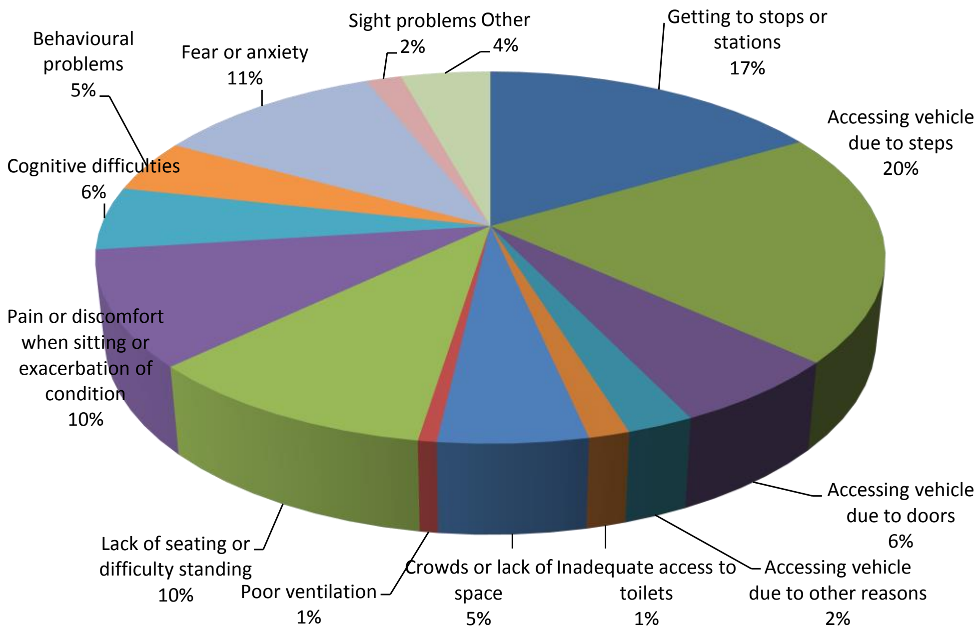
We note that the above general discussion does not apply to people in the region who, perhaps for reasons of disability, cannot access a bus but could access an LRV. This might occur, for example because they utilise wheelchairs or other mobility aids which are too big to fit into a bus. For such people, having access to an LRV service would undoubtedly be beneficial.

The most recent Census indicates that there are some 378 people in the SA1s which lie either side of the proposed LRS who have a need for assistance in

[40] Current bus services further north, into Bridgewater and particularly Brighton and New Norfolk are much less frequent, and arguably sub-optimal from the perspective of providing access. We note further that increasing bus frequency is a much less expensive proposition than the proposed light rail service, which in any case only extends to Glenorchy.

core activities; the basic measure of disability in the Census.[41] No more details are yet available from the most recent Census, but another ABS publication (ABS, 2009) has a more detailed analysis of disability, including experience with public transport, using slightly more dated data. This publication, which covers all of Hobart, rather than the study area itself, suggests that roughly two-thirds of people with disabilities have no difficulties using public transport. Moreover, around 75 percent of people with disabilities in Hobart could use all available public transport (some with assistance or difficulties), nine percent could use some forms of public transport (again, some with assistance or difficulty) and 15 percent could use no forms of public transport. Note that this refers to existing forms of public transport in Hobart. If the same proportions are applied to the gross count of people with disabilities in the SA1s along the track in the most recent Census, this would imply that around 126 (one third) have some difficulties using public transport and thus might be assisted by this new mode, and that 57 (15 percent) who currently don't access public transport might be able to do so with the new mode. The same publication goes further, in examining the reasons why people have difficulties (the one third above) accessing public transport. These are shown in Figure 10.

Figure 10 **Reasons for difficulty accessing public transport in Hobart**



Data source: ABS Cat no 4430.0

[41] Those further away would need to catch a feeder bus to the line, so although they would add a new potential mode to their existing public transport trip, they would still face exactly the same barriers to the first step of that trip in that they would need to get to a bus.

The main aspects which differ from existing public transport services and the proposed light rail are those associated with access to the vehicle, which comprise (in total) 28 percent of the total. Getting to the stop will not be affected because existing bus stops are almost always closer than the proposed LRV stop because there are so many of them in the region. Reasons associated with the person themselves such as sight problems, behavioural problems or pain when sitting will not be altered by the light rail compared to a bus, except perhaps for some for whom rail seats are more comfortable, and crowding or a lack of seating will, if the light rail is well-patronised, likely be similar to existing buses. Thus, again applying Hobart-wide proportions to the population represented, we have 106 people who are currently accessing public transport with some difficulty and might see their situation improved. Added to the 57 people above who are not able to use public transport at all but who might be able to access an LRV, and we have a maximum potential market size of 163 people. For around two-thirds of these people, the issue is one of improved access, not new access (and thus a smaller gain in social welfare than if they had no access at all), and for the remaining third, we do not have any data as to how many people who currently cannot access a bus could physically access an LRV. This might be much smaller than the 57 people mentioned above. This suggests a relatively minor increase in social welfare associated with the light rail system for people with disabilities in Hobart.

The above methodology is approximate. It assumes that the proportions of people in different categories in regards to their experience with public transport is the same in the study area as it is in Hobart as a whole. It also assumes that the numbers of people with disabilities in the study will stay roughly the same (with some natural population growth), rather than assuming that people with disabilities will move to the area (either of their own volition or by government planning) to gain access to better public transport than from their current place of residence. However, it suggests that, in rough orders of magnitude, the LRS would result at best in some improvements in the social welfare of somewhere between 150 and 200 people with disabilities; with the caveat that most of these already have access and the issue is one of reduced difficulty. Any improvement in the social welfare of people with disabilities is, of course, a worthwhile goal of public policy. However, given the numbers of people likely to be involved, it seems likely that targeted community transport initiatives might be a more effective and much less costly way of targeting the transport needs of this sector of the community.

In summary, equity and distributional issues are a vitally important consideration for public transport and one which must necessarily be foremost in the minds of public transport planners. Moreover, the region through which the LRS will run, and the wider region it will serve through its feeder-bus network is precisely the region, due to its socio-economic characteristics that government ought to make its priority in Hobart, for the provision of better public transport to improve access. Considered in isolation, therefore, the proposed LRS has important equity and distributional benefits. However, when one considers the counterfactual of existing bus services (or indeed, improvements which could be made at much lower cost than required for the light rail system), the marginal improvement that the system provides over existing public transport from the perspective of equity and social justice is considered to be very small.

5.4 Wider economic benefits

One aspect of the proposed LRS which has been raised by stakeholders is its wider economic benefits. IA treats wider economic benefits separately from benefit cost assessments, and encourages those making submissions to consult with it before proceeding with any analysis. It also notes that consideration of wider economic benefits is an area where the development of techniques is "in its infancy" (IA, 2012, p29), and suggests that any such benefits are likely to occur only where "traditional" benefits are very strong.

Within the context of wider economic benefits, IA recognises the following:

- Agglomeration economies.
- The removal of imperfections in labour and other markets.
- Deepening of labour markets.

IA does not suggest that its list is exhaustive, and to this list one could conceivably add the development benefits that occur with the development of an LRS as, say, the region immediately surrounding it increases in density and new housing stock is created. There are thus four potential benefits.

In relation to market imperfections, a major difficulty exists in relation to calculability. Lancaster & Lipsey (1956) show in a seminal paper, that, where several imperfectly competitive industries exist in an economy, it is generally impossible to even predict the sign of the welfare change that is associated with increasing competitiveness in one sector. The result is that almost no infrastructure proponents have endeavoured to advance arguments on the basis of changes in market competitiveness (See Hazeldine et al, 2013).

Agglomeration economies are, loosely speaking, the increase in productivity (which can be internal to a firm, and industry or a geographical location) which arise because firms and/or people are co-located. They can be affected by transport because improvements in transport links can have the effect of bringing two areas closer together by reducing the time taken to travel between them. In the particular case of Hobart, they might increase employment density in some locations (chiefly Central Hobart itself) and thus increase productivity in these regions.[42] In this respect, agglomeration and labour market deepening can be treated as one, and we thus consider agglomeration economies and development benefits as our key issues below. By including the discussion below (and in Appendix D), we go beyond the scope of the study as defined by our contract with DIER. However, many stakeholders have raised these issues as being important, and we consider it useful to provide at least some background on each, so that DIER can make a determination as to whether further study is worthwhile in bolstering the case for light rail.

Agglomeration economies

As noted above, agglomeration economies pertain to the increase in productivity associated with an increase in density. There is a considerable literature on agglomeration economies, but this does not mean that they are a "settled" issue. There is still considerable debate about what actually drives the observed increases in productivity (and indeed on whether the direction of causation runs from density to productivity, or from productivity to density), and on the size of agglomeration economies in light of other potential factors which might also drive productivity gains in a particular location. Attempting to settle these issues via empirical investigation throws up a number of econometric issues which have not been definitively addressed in the literature.

There is also debate about whether agglomeration economies are mainly associated at the industry level (meaning many firms in the same industry in the same place receive a productivity benefit) or whether they are associated at the urban level (meaning many different industries in a given location produce productivity gains, as Jacobs suggests in her seminal work from 1961 on US cities). These are known as localisation (Marshallian) and urbanisation (Jacobs) externalities in the literature.

If agglomeration economies are mostly associated with localisation, rather than urbanisation, then the appropriate policy response may revolve around the promotion of industry clusters, within which transport policy might play only a relatively minor role. If there is uncertainty about what exactly are the driving forces of agglomeration economies (of either type) where they have been observed, then this means that lessons from other cities might have limited applicability in the context being studied. Both are important for policymakers, and highlights the major problems associated with devising policy around interesting theories rather than solid empirical evidence and, more particularly, the folly of mechanistic calculations without understanding what lies behind them.

[42] Equally, it might disperse employment; a factor we do not consider in our analysis.

We summarise the debate on agglomeration economies in Appendix D, paying particular focus on the difficulties in establishing what they are and how they operate, and in pointing out the logical fallacies which result from making assumptions such as those outlined in the previous paragraph. In short, we concur with IA's caution about agglomeration economies (as an empirically verifiable phenomenon, not as a concept; we do not suggest that the concept is flawed, but rather that it is hard to measure), but we provide much more detail on the reasoning behind our consideration than is possible in the succinct IA guidelines.

The fact that there is still considerable debate around agglomeration economies has not prevented work being done to try and calculate them and, more particularly, to calculate how particular transport initiatives might create agglomeration economies.[43] This is perhaps most advanced, at least in the policy sense, in the UK and New Zealand, where relatively simple models exist to enable the calculation of agglomeration economies. These models exist in part because of empirical work done in both countries (see Appendix D) to establish the relevant elasticities that allow one to understand how a given increase in density translates into a particular increase in productivity, but also because data exist in both countries which facilitate the key empirical work in the first instance. The same kind of spatial data do not exist in Australia, which makes replication of the empirical work that derives the relevant elasticities problematic (See Appendix D).

An examination of agglomeration economies sits outside the scope of this project. However, a number of stakeholders have expressed an interest in the topic, and on the potential effects of the proposed light rail system in respect of agglomeration economies in Hobart. We have thus conducted a fairly cursory examination of the topic, using extant UK elasticities and the same modelling approach as in the UK (see Appendix D for details). In so doing, we follow a similar path as has recently been followed in Victoria (See Vic DoT, 2012) and we would note that the criticisms of that review most certainly apply here, and that our estimates are almost certainly much too large.[44] However, from the perspective of providing an initial base estimate, which might provide a motivation for more detailed research at a later stage, we

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[43] We speak here of serious work. There are a great many unproven ambit claims made about particular projects.

[44] There is no evidence to suggest the elasticity linking changes in density to changes in productivity is constant at different levels of density. It seems highly unlikely that increasing the density of a small country town by ten percent would have the same (proportional) effect on productivity as increasing the density of London by ten percent. Since Hobart is much less dense than the UK cities from which the relevant elasticities have been calculated, this almost certainly means that the elasticity is much too large, and thus that our agglomeration economy estimates are grossly overstated.

consider it adequate. The results of our analysis are an annual agglomeration effect of roughly $600,000. This represents around six percent of the benefits stream in the headline analysis shown in Table 6, or 0.01 percent of the gross regional product of the city.

Development effects

Development effects refer to the fact that investment in light rail infrastructure can provide a stimulus for urban renewal and development. Recent articles in the *Mercury* have suggested, respectively, that these effects could increase land values between 15 and 20, and 5 and 25 percent.[45]

The figures appear, on the face of the international evidence we have seen, to be excessive; Duncan (2008) in a review of US studies suggests that, although higher numbers are recorded in some instances, there are difficulties in generalising because of different methodologies, and that the most that can be said in a general sense is that premiums are likely to be less than ten percent (at least for residential properties). Edge (2003), reviewing UK studies, suggests between five and ten percent, with increases of between ten and 30 percent for commercial properties. Billings (2011) makes the point that very few studies adequately compensate for "neighbourhood" effects (the fact that prices in a region might be rising for reasons not directly tied to the railway) and laments that many studies fail to pick their counterfactual comparisons with due diligence (or ignore them altogether).

However, the most important aspect of these international reviews is not the actual numbers themselves; the wide ranges above show that there are no "definitive" answers. Rather, most authors point to the fact that it is context that is most important. For example:

- Hess & Almeida (2007) and Diaz (1999) suggest that the railway in question needs to be solving a key congestion issue; if most people in the area are not overly affected by congestion and are thus unlikely to utilise the railway to overcome it, then they will not pay a premium to live near the railway.
- Duncan (2008) suggests the type of housing around the station matters, with apartments experiencing a premium of 17 percent compared to six percent for single family dwellings. However, he notes that most studies

[45] See www.themercury.com.au/article/2013/02/15/372415_todays-news.html and www.themercury.com.au/article/2013/04/14/376897_real-estate-news.html. Note also that the larger are the claims for development effects, the smaller is the funding Tasmania is likely to receive from the Federal Government, because large development benefits are a prima facie case for user-pays funding of infrastructure. To the extent that Tasmania seeks funding from the Federal Government, it ought to be very careful not to over-estimate development effects.

undertaken have focussed on single family homes, meaning the breadth of findings on the impacts on apartments is smaller.

- Kahn (2007) notes the importance of complementary land use planning policies (and the failure of most studies to include this), and the importance of local government support for denser developments around railways. Kolko (2011) notes similar issues in a study of the Californian experience, and notes that jobs growth in particular, is difficult to engender. Giuliano & Agarwal (2010) go so far to say that it is the pro-growth policies that are important, more than the railway which is itself a manifestation of such policies.
- Cervero, Ferrell, & Murphy (2002) note the importance of prevailing economic conditions. In times of anaemic economic growth and/or low population growth, prices for land are unlikely to increase as much. Giuliano & Agarwal (2010) make the further point that, because economic activity and preferences about where to live change through time in a spatial sense, the price effects that were hoped for by planners do not always eventuate.

All of this evidence suggests that "benchmark" figures from other cities are of limited use in predicting what might happen in Hobart, and that what is actually required is a detailed study of the land market in Hobart. Perhaps more importantly, community consultation is also vital; the economic literature is just not accurate or definitive enough to impose a value capture tax on a community based on an "objective" assessment.

Neither the detailed study nor the community consultation has occurred. However, the recent work undertaken by DED for Macquarie Point suggests that caution should be given to the upper ranges of the estimate cited in the above *Mercury* articles. Despite being almost ideally located for high density living, the report (AEC Group, 2012) suggests demand of between 15 and 45 residential units per annum over a 20-year period, citing anaemic demand growth in Hobart as a key reason for these low figures. This is suggestive of a relatively low premium associated with the development of an LRS in any potential TOD area.

Even after the requisite work is done to establish likely demand for TOD properties and how the LRS might influence real estate prices in Hobart, there are three very important reasons why any local (gross) effects might translate into smaller (net) effects on a city-wide basis.

The first of these is that, if the benefits of higher-quality housing, shops, restaurants and other amenities are to be included, then the cost of developing these needs to also be included. For example, if the development of a transit-oriented development zone around an LRV stop sees two existing houses worth $500,000 each replaced by ten apartments selling for $400,000 each, the net benefit is not $3 million, because this ignores the cost of constructing the ten apartments. For a net benefit to occur in this instance, the apartments would have to have a construction cost of less than $300,000 each. Similar arguments can be made for the shops, restaurants, parks and other amenities in a transit-oriented development zone; whilst it is accurate (generally, though not always) to say that the light rail system was the catalyst for, say, $4 million of new apartments, it is not accurate to say that a benefit of the light rail system is $4 million in new apartments.

Related to this is the issue of double-counting. In the example of the apartments above, say they cost $380,000 to construct, and sell for $400,000.[46] Where does the $20,000 premium come from? If it comes from the fact that the conveniently-located apartments provide travel-time savings for those who purchase them by virtue of their location near the line, then this has already been captured in the benefit cost analysis, as outlined above. Counting the real estate value increase would be double-counting.

The third and final issue is the choice of the counter-factual. This has two elements. Firstly, was the LRS itself the only way in which a transit-oriented development could have progressed? If it could have progressed around a bus-way (or some other transport link providing a similar service) then it is only the net benefit that the LRS provides that no other "transport core" to the development could. Secondly, what happens to property investment throughout the rest of the city? If the only effect of a transit-oriented development is to shift investment from one part of the city to another, then it has not increased net welfare from the perspective of the city as a whole.[47]

These three effects mean that the city-wide, net impact may in fact be very small. Indeed, what may actually occur is a redistribution of investment from the rest of the city to the area around the light rail system. This may be desirable, and part of Tasmanian Government policy, but it needs to be made clear in the context of the public debate; government are not, after all, real estate spruikers for a favoured region of the city.

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[46] In this instance, there would not be a net benefit, because of the destruction of $1 million in housing stock to build the apartments.

[47] A city authority might choose to invest public funds if the area gaining investment was poorer, or had some other form of social disadvantage compared to the areas where investment declines. This is a legitimate reason for public investment, but it involves the city authority taking a view about the desirable socio-economic distribution within its jurisdiction. This is a subjective issue, properly considered within a democratic framework of governance and decision-making, not something for an objective review conducted by outside consultants who do not have the relevant mandate to make judgements on the appropriate distribution of wealth within a city. However, it is worth pointing out that "gentrifying" an area is not always beneficial to its poorer inhabitants; a topic on which Jane Jacobs (1961) writes eloquently in the context of US cities.

For the reasons outlined above, our initial conclusions are that a very powerful case would need to be made in regards to development effects for these to form a key part of any assessment of the overall benefits associated with the light rail system. However, this does not mean that arguments about development effects are unimportant. They are, in fact, very important to help build the case about how the system might be funded.

Levinson & Istrate (2011), Litman (2013) and Doherty (2004) provide three different reviews of the wide range of funding options for infrastructure development, none of which have been considered to date. Not all are appropriate in the Hobart context, but the Tasmanian government may find that it is able to obtain considerable leverage from any Federal Government funding by exploring some of these options. This makes understanding development effects, even if they are only local, an important consideration (certainly too important to be based on "benchmarks" from other cities what do not take the unique characteristics of Hobart into account), as is outlined in Box 2 below.

Box 2 **Why consider property market effects?**

Consider a development which adds nothing in a net sense to the city in which it is created, but which only shifts the location of investment that would otherwise have occurred. Consider further that this development has no benefits from a distributional perspective by way of rejuvenating an impoverished area. There would therefore be no prima-facie reason for public investment in such a development.

However, knowing the local property market effects can still be important, even crucial. This is because it provides information on how the project might be funded. In this hypothetical example, the local increase in property value might still be significant. If the relevant area is already populated by private property owners (residential or commercial) and the light rail system is likely to significantly increase the value of their land, then there may be scope to levy taxes on landholder via a "value capture" mechanism. Alternatively, if the land is derelict, or being put to low value use, or in public hands (or all three), there may be scope to package the land together, and use it as the core of a public-private partnership, whereby the developer of the land receives it at a discounted rate (though still higher than its value in use absent of the light rail system, to prevent public subsidy of a private developer) in exchange for funding or part-funding the system.

Few cases are as black and white as no public benefits and significant private benefits, which suggests that, in most cases, the relevant case will be a mix of public and private funds. Understanding localised benefits is therefore crucial for government to understand how it can leverage its own funding with the private sector, to increase the likelihood of a particular project going ahead.

6 Sensitivity Analysis

Any benefit cost assessment, because it is based upon only a fairly narrow range of scenarios concerning the future, ought to be subject to sensitivity analysis. This allows one to test the robustness of the different findings under different assumptions; if the benefit cost ratio falls rapidly with a small increase in costs then, since infrastructure costs frequently rise in the course of construction compared to forecasts,[48] this could be a reason not to go ahead with the project.

We have already considered a crucial piece of sensitivity analysis centred around the demand side of the model in Section 4.2. In this chapter, we conduct an analysis based around the more "standard" parameters which IA would expect to see in a benefit costs analysis. In this respect, the chapter responds to the criticism of AECOM (2012) that our previous sensitivity analysis (ACIL Tasman, 2011) was non-standard, and we have made use of the template used by AECOM in its review for our analysis this time around, with some changes to reflect the fact that several of the items in AECOM's (2012) review can be treated together in our model (accident costs, vehicle operating costs and externalities, which all enter the model on a cost per km travelled basis) and to add a consideration of different population growth rates. We thus consider the following:

- Increasing and decreasing capital costs by 20 percent.
- Increasing and decreasing light rail operating costs by 20 percent.
- Increasing and decreasing the value of accidents, vehicle costs and externalities by 20 percent.
- Increasing and decreasing the value of travel time savings (that is, the value of time on an hourly basis) by 40 percent.
- Adding construction delays of one and five years.
- Doubling population growth and setting population growth to zero (adding 0.65 percentage points per annum to our core figures).

6.1 Sensitivity analysis results

In this section, we provide the results of our sensitivity analysis, associated with the dot points above. Where results lead to similar conclusions, we group the relevant tables.

[48] See Flyvbjerg (2007); for railways, the average is 44 percent.

Table 9 **Increasing capital expenditure by 20 percent**

	OOSM 1	OOSM 2	OOSM 3	OOSM 4
BCR				
4%	1.26	1.19	1.19	0.95
7%	0.90	0.85	0.84	0.65
10%	0.67	0.63	0.63	0.51
NPV				
4%	$24,057,000	$17,321,000	$17,272,000	-$4,602,000
7%	-$8,867,000	-$13,295,000	-$13,383,000	-$30,396,000
10%	-$26,282,000	-$29,378,000	-$29,493,000	-$43,433,000
IRR	6%	5%	5%	4%

Table 10 **Decreasing capital expenditure by 20 percent**

	OOSM 1	OOSM 2	OOSM 3	OOSM 4
BCR				
4%	2.06	1.95	1.94	1.60
7%	1.46	1.38	1.38	1.14
10%	1.09	1.04	1.04	0.85
NPV				
4%	$64,595,000	$58,073,000	$58,239,000	$40,426,000
7%	$26,278,000	$22,036,000	$22,135,000	$8,643,000
10%	$5,012,000	$2,083,000	$2,132,000	-$8,672,000
IRR	11%	10%	10%	8%

Table 11 **Increasing operating costs by 20 percent**

	OOSM 1	OOSM 2	OOSM 3	OOSM 4
BCR				
4%	1.48	1.41	1.41	1.12
7%	1.05	1.00	1.00	0.80
10%	0.79	0.75	0.75	0.60
NPV				
4%	$36,8823,000	$31,285,000	$31,343,000	$10,567,000
7%	$3,843,000	$197,000	$203,000	-$15,674,000
10%	-$14,004,000	-$16,529,000	-$16,562,000	-$29,375,000
IRR	8%	7%	7%	5%

Table 12 **Decreasing operating costs by 20 percent**

	OOSM 1	OOSM 2	OOSM 3	OOSM 4
BCR				
4%	1.68	1.57	1.57	1.30
7%	1.19	1.12	1.12	0.92
10%	0.89	0.84	0.84	0.69
NPV				
4%	$51,769,000	$44,109,000	$44,167,000	$25,257,000
7%	$13,569,000	$8,544,000	$8,549,000	-$6,079,000
10%	-$7,267,000	-$10,766,000	-$10,799,000	-$22,730,000
IRR	9%	8%	8%	6%

Changing capital costs or operating costs has the expected effect; increases in costs reduce benefits and reductions in costs increase net benefits. Moreover, since these cases are associated with the cost side of the equation, and have no effect on demand, the effects are (roughly) proportional to the change in the cost parameters.

Table 13 **Decreasing and increasing accident, vehicle and externality costs by 20 percent – OOSM1**

	20% increase	20 % decrease
BCR		
4%	1.54	1.29
7%	1.09	0.92
10%	0.82	0.69
NPV		
4%	$41,107,000	$22,225,000
7%	$6,577,000	-$5,753,000
10%	-$12,122,000	-$20,632,000
IRR	8%	6%

In this instance, we have only re-run the model for OOSM1, where the effects are greatest. The accident, vehicle operating and externality costs are only a very small part of overall costs, and thus increasing them makes very little difference compared to our core results. The small differences that are apparent occur because the base case changes slightly as well, but they are not significant. Decreasing these costs, however, makes a car slightly better than other modes of transport, and this has a reasonably large impact on the BCR, as the model is sensitive to small changes in relative costs.

Table 14 **Changing the value of travel time savings – OOSM 1**

	40 % increase	20 % decrease
BCR		
4%	0.13	1.78
7%	0.10	1.26
10%	0.07	0.97
NPV		
4%	-$66,124,000	$59,535,000
7%	-$64,307,000	$18,777,000
10%	-$61,640,000	-$3,585,000
IRR	n/a	9%

Changes in travel time values have a direct effect on demand and thus, unlike the case for changes in costs, they have a more than proportional effect. Note that, because this sensitivity analysis requires us to re-run PTEAM, we have only presented results for OOSM 1, although the other OOSMs would exhibit similar effects. Here the most surprising result is the effect of the increase in the value of travel time, which results in a collapse in demand. The issue is that both car and public transport trips have fixed and variable cost elements. For the car, parking is a fixed cost, while for public transport, ticket prices are fixed; for both, all other elements are on a per kilometre basis. Public transport, including the LRV, is actually slower than a car. However, the fixed costs are smaller. Increasing the value of travel time has the effect of increasing the importance of variable cost elements and decreasing the importance of fixed costs elements. In this instance the relevant changes have meant that the fixed cost advantage for public transport no longer outweighs the slightly longer trip times, and thus demand collapses.

Table 15 **Construction delay of one year**

	OOSM 1	OOSM 2	OOSM 3	OOSM 4
BCR				
4%	1.56	1.47	1.47	1.20
7%	1.12	1.06	1.06	0.86
10%	0.84	0.80	0.80	0.65
NPV				
4%	$41,380,000	$34,950,000	$34,933,000	$16,074,000
7%	$7,971,000	$3,824,000	$3,773,000	-$10,397,000
10%	-$9,493,000	-$12,327,000	-$12,400,000	-$23,616,000
IRR	8%	7%	8%	6%

Table 16 **Construction delay of five years**

	OOSM 1	OOSM 2	OOSM 3	OOSM 4
BCR				
4%	1.48	1.39	1.38	1.13
7%	1.10	1.03	1.03	0.84
10%	0.84	0.79	0.79	0.65
NPV				
4%	$29,901,000	$24,425,000	$24,199,000	$8,917,000
7%	$4,836,000	$1,518,000	$1,328,000	-$9,173,000
10%	-$6,405,000	-$8,516,000	-$8,674,000	-$16,221,000
IRR	8%	7%	7%	5%

Changing the timeframe of construction has only a limited effect on BCRs. This is because the costs and the benefits are delayed. Inherent in the analyses above, however, is an assumption that funding is not committed until the shovels are ready to turn; if government committed the money and then left it idle for five years while it worked through planning delays, BCRs would fall. However, it seems unlikely that this would occur; even if money is allocated before construction is ready to begin, it is usually put into some kind of interest-bearing account which grows in value, rather than simply being left as cash.

Table 17 **Doubling population growth**

	OOSM 1	OOSM 2	OOSM 3	OOSM 4
BCR				
4%	1.68	1.58	1.57	1.27
7%	1.19	1.12	1.12	0.90
10%	0.89	0.84	0.84	0.68
NPV				
4%	$52,221,000	$44,202,000	$44,220,000	$22,514,000
7%	$13,838,000	$8,547,000	$8,444,000	-$7,846,000
10%	-$7,058,000	-$10,770,000	-$10,931,000	-$23,918,000
IRR	9%	8%	8%	6%

Table 18 **Zero population growth**

	OOSM 1	OOSM 2	OOSM 3	OOSM 4
BCR				
4%	1.28	1.24	1.26	1.00
7%	0.92	0.90	0.91	0.73
10%	0.70	0.68	0.69	0.55
NPV				
4%	$21,032,000	$18,180,000	$19,941,000	$394,000
7%	-$5,440,000	-$7,454,000	-$6,383,000	-$21,468,000
10%	-$19,748,000	-$21,255,000	-$20,584,000	-$32,856,000
IRR	6%	5%	6%	4%

The population figures show the importance of a growing railway on the BCR; with zero population growth, the railway will only deliver a net social benefit at the four percent discount rate (actually, it will break even at six percent). With a decline in population, the benefit cost ratios would obviously fall still further.

7 Conclusions

This report examines the benefits and costs associated with the development of a light rail system linking Central Hobart with Glenorchy. We examine four different optimal models, incorporating different trade-offs between speed and accessibility. On balance, the most rapid transit model is also the one which provides the greatest benefits, which is perhaps unsurprising given the locus of population at Glenorchy and of employment in Hobart and to a lesser extent Glenorchy.

The headline results of the analysis suggest reasonable benefits from the development of the light rail system, with benefit cost ratios of between 1.12 and 1.58 for the four and seven percent discount rate cases for the best performing model (OOSM 1, with others slightly behind).

However, the headline results are based on a series of assumptions, some of which are "non-standard" in the context of the ATC *Guidelines* (2006), widely used in benefit cost analysis in Australia. This does not mean that the assumptions are wrong, necessarily (although we would suggest they are the very optimistic end of what is feasible), but rather that they are likely to be challenged by those assessing our work. We therefore present an alternative set of results based on more standard values for the relevant assumptions. In particular, putting in the "standard" values for the relevant parameter with greatest effect, the transfer penalty, produces benefit cost ratios of zero; to achieve a BCR greater than one (with a discount rate of seven percent, for OOSM 1), a transfer penalty smaller than one minute is required. Additionally, the results are very sensitive to the value of travel time used; a sensitivity which, moreover, is asymmetric, with larger values of travel time reducing benefit cost ratios substantially, but decreases in travel time values not changing results substantially. This suggests that the headline results should not be used alone in assessing the viability of the proposed light rail system.

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Appendix B Detail on PTEAM

In this appendix, we provide further detail on the way in which the model operates, specifically:

- The formation of the cost functions.
- The assumptions underpinning directed and non-directed travel.
- The formation of the demand curves and the calculation of consumer surpluses.
- A cross-check between the model results and empirical data from Hobart and other cities to ensure the results are realistic.

B.1 Formation of the cost functions

As noted above, the cost functions include all of the resource costs associated with transport. Specifically:

- The costs of bus and LRV tickets.
- The costs of fuel and vehicle operation.
- The costs of parking.
- The value of time spent travelling in congested and uncongested streets.
- The societal cost of environmental pollution.
- The costs of road crashes.

These elements are combined in cost functions for each of the five trips outlined above which incorporate three basic elements:

- A cash cost in the form of ticket prices or fuel and parking costs.
- A travel time and (except for cars) waiting time cost.
- A per kilometre value for pollution and road crashes.

The resultant cost functions are shown below. The cost functions used are based on a utility function developed by Parry & Small (2009). In this framework the cost of travel is determined by the direct monetary expenses as well as the time spent travelling, waiting and accessing each mode and external effects such as pollution. Furthermore we have introduced two speed zones in order to take urban congestion into account. The variables and parameters of the cost function are shown in Table B1.

Table B1 **Variables of the cost functions**

Description	Variable name	Affected mode
Distance to destination car	*DC*	Car
Distance to destination bus	*DB*	Bus
Distance to destination LRV	*DT*	LRV
Distance to closest LRV stop feeder	*DF*	Feeder (train)
Distance to closest P&R	*DPR*	P&R (train)
Distance to closest bus stop	*WD_B*	Bus
Distance to closest LRV stop	*WD_T*	LRV
Distance to closest feeder stop	*WD_F*	Feeder (train)
Average speed car outer sector	*CSo*	Car
Average speed car inner sector	*CSi*	Car
Average speed bus outer sector	*BSo*	Bus
Average speed bus inner sector	*BSi*	Bus
Average speed LRV	*TS*	LRV (feeder and P&R)
Average speed walking	*WS*	Bus
Waiting time	*WT*	Bus
Fuel price	*FP*	Car
Average fuel consumption	*FC*	Car
Ticket price	*TP*	Bus
Value of travel time	*VTT*	Car and Bus
Parking cost	*PC*	Car
Pollution cost	*EPC*	Car
Road crash cost	*ERC*	Car

The cost functions (*C*) by mode are:

$$C_{Car} = DC * FC * FP + \frac{DC-ID}{CSo} * VTT + \frac{ID}{CSi} * VTT + EPC * DC + ERC * DC + PC$$

$$C_{Bus} = TP + \frac{WD_B}{WS} * VTT + WT * VTT + \frac{DB-ID}{BSo} * VTT + \frac{ID}{BSi} * VTT$$

$$C_{Train} = TP + \frac{WD_T}{WS} * VTT + WT * VTT + \frac{DT}{TS} * VTT$$

$$C_{Feeder} = TP + \frac{WD_F}{WS} * VTT + WT * VTT + \frac{DF}{BSo} * VTT + \frac{DT}{TS} * VTT$$

$$C_{P\&R} = TP + \frac{DPR}{BSo} * VTT + WT * VTT + \frac{DT}{TS} * VTT$$

Where relevant, cost components are adjusted to their perceived values, i.e. time spent waiting is perceived to be longer than time spent moving, based on various multipliers. The relevant multipliers are published by the ATC (2006) and are considered standard in benefit cost analysis in Australia. They are shown in Table B2.

Table B2 **Cost multipliers**

Perceived cost unit values	Low	Normal	High	Unit
Access weighting (short, medium long walk)	1.2	1.4	1.8	Multiplier
Wait weighting	1.4	2		Multiplier
In-vehicle weighting (LRV, bus)	0.75	1		Multiplier
LRV productivity reduction		0.85		Multiplier

Data source: Australian Transport Council (2006)

We now discuss the parameters of each of these cost functions in more detail.

Cost function parameters

In this section, we provide an overview of each of the parameters used in the cost functions outlined above. Before doing so, it is important to digress slightly and explore a parameter not explicitly mentioned in each cost function; the area from which each representative consumer comes. We have chosen 535 Census Statistical Areas 1 throughout Hobart (see Figure 1in Chapter 2) to obtain representative consumers. The basic assumption is that each representative consumer lives at the centre of each collection district and travels in a straight line to the closest transport corridor access point (e.g. a n arterial road, a bus or a LRV stop) and then follows a predetermined route to his destination. We delineate between employed people, students and the unemployed in each SA1.

Most of our parameters are associated with vehicle speeds, as it is travel times which drive much of the resource costs. Data on vehicle speeds have come from studies by DIER (2011) and DIER unpublished data in respect to bus speeds. We assume that speeds drop from free-flow speeds to congested speeds at a certain point along each route, and we allow all speeds (except those of the LRS) to vary in the creation of demand functions. Fuel prices (which we also allow to vary) are from time series analysis of DIER data while those on road crashes, externalities, waiting time penalties etc. come from the ATC (2006). Other parameter information is provided below.

Average fuel consumption

In 2002 the ABS conducted a detailed survey on fuel consumption in Australia in which it reports total fuel consumption in this year (ABS, 2002). BITRE (2009), in turn, provides figures on the total number of driven kilometres per year, state and vehicle class. From these datasets we calculated an average consumption per kilometre. The resulting value is 7.2 litres per 100km. We applied a mark-up to account for inner city driving.

Ticket price

The value of the ticket price ($3.00 for directed and $2.00 and for non-directed travel) is result of discussions with DIER and reflect an average price as perceived by passengers for travel in the Northern suburbs. We use this figure because it drives consumer choice. Non-directed travel is generally cheaper with discounts for day tickets.

Parking cost

We assume the average expected parking cost in Hobart to be $8 per day. Parking a car accounts for two commuter trips (one to work and one home again), and the average ridership per car is 1.2 people, hence the cost per person per trip of car parking is $3.30.

B.2 Assumptions underpinning directed and non-directed travel

The cost functions outlined in the previous section are applied to directed and non-directed travel. Directed travel is the travel between a given Census SA1 and a given place of work or education, whilst undirected travel is travel from a given Census SA1 to a given attractor. In this section, we detail further the assumptions underpinning these trips.

Directed travel

As noted previously, directed travel essentially involves travel from home to work or school (and back). The only relevant choice is overall resource cost, which representative consumers are assumed to minimise.

Work trips are undertaken by all employed people (based on Census data) in each SA1 who are over the age of 15. We are constricted somewhat by age bands in the Census data in this respect, and we thus assume that all people between the ages of 15 and 19 who travel for work do so by public transport. This likely over-estimates public transport travel somewhat, as some of these people will have a licence and a car, and will drive to work. However, the numbers of people are not large. All people 20 and above have the full choice between the five types of trip outlined previously.

Work locations are

- The centre of Hobart (54 per cent of all directed trips),
- Glenorchy (20%),
- Kingston (9%),
- Clarence (15%) and

- Brighton (2%).

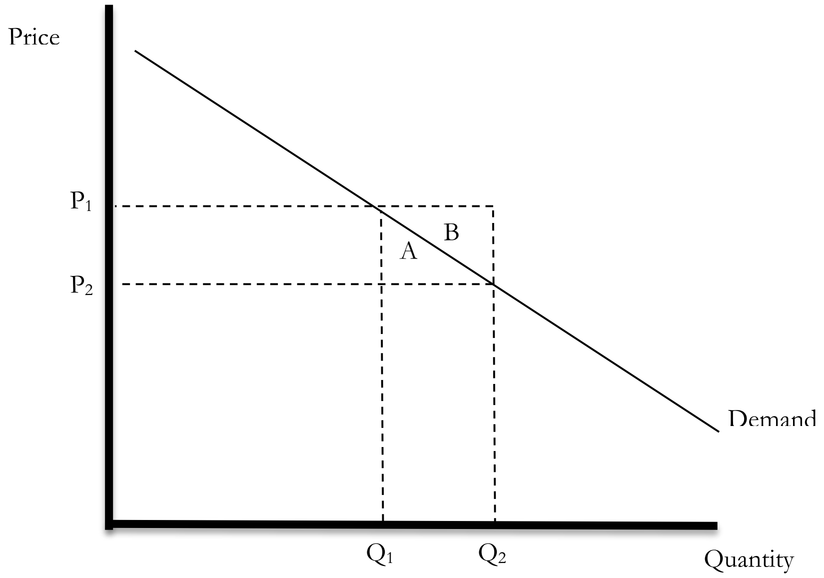
The above are based upon Census data on the numbers of people employed in these local government areas. We recognise that employment is spread more widely than this, but the level of data required to fully specify work origins and destinations does not exist at present, and it is beyond the scope of this analysis to collect it. However, since the main focus of the analysis is to estimate the benefits associated with the LRS, the problem is not overly large; we will over-estimate the consumer surplus associated with each mode by making trips longer than they actually are, but our main focus is the change wrought in consumer surplus as the LRS is introduced, and this is not affected if all trip types are affected equally.

School trips are estimated based upon those identifying themselves in the Census as being students. Those less than 15 are assumed to walk or be driven to school. Those between 15 and 19 are assumed to take public transport if the nearest stop is closer than 800m (which it usually is). Those over 19 have the full choice of modes. DIER has provides us with origin destination data for most schools in Hobart. Using this data we estimated the share of trips from each Census SA1 to the five work locations.

Rule of halves for generated trips

In discussing the sparks effect, AECOM suggested that the "rule of halves" should be applied for any generated or induced trips. The rule of halves is intended to proxy the change in consumer surplus which arises when demand increases in a model where the benefits are set based upon an average or representative person. Its name arises because a triangle has half the area of a rectangle if its corners coincide with those of the rectangle. Figure B1explains in more detail. Price changes from P_1 to P_2, inducing a quantity shift from Q_1 to Q_2. The consumer surplus is the triangle A, but if we are basing our benefits calculation on the experience of the marginal consumer at Q_1 and we effectively move her out to Q_2 without taking note of the change in price, we will calculate an area of A+B, which is twice the consumer surplus.

Figure B1 **Rule of halves**



Our model does not base itself on the experience of a single, average consumer. Instead, it seeks to derive the demand curve, and then calculate the consumer surplus directly. Thus, when evaluating the change from Q_1 to Q_2, the model calculates the area A directly, not A+B. There is therefore not a need to halve the benefits for induced trips.

Non-directed travel specific assumptions

In the previous iteration (ACIL Tasman, 2011) every relevant person made a round trip journey covering a pre-defined distance in the mode associated with the lowest total resource cost. While it robustly predicted mode shares the model did not analyse travel patterns. For this iteration we developed a gravity model for the Hobart leisure travel market.

The gravity model comprises nine key destinations, each associated with a certain intrinsic attractiveness.[49] This intrinsic attractiveness can be interpreted as the frequency a person would visit a certain attraction if the cost of travelling to all attractions was identical. Since this is usually not the case, the intrinsic attractiveness is adjusted by the cost associated with travelling to each attraction. This means that every representative consumer has a different travel pattern. The individual travel patterns can change when the (public) transport network is altered.

For example, suppose there are only two destinations (say A and B) with an identical intrinsic attractiveness. A person who lives right in the middle of

[49] This is based on feedback from DIER; there are no data that we are aware of the intrinsic attractiveness of different locations in Hobart.

these two would visit A as often as B. A person whose travel costs to A are twice as high as those to B, the travel cost adjusted attractiveness of A would be a third of B's. Hence, for a total of say 100 trips, the second person would go to A 25 times and to B 75 times. If the transport network was changed such that the second person's travel cost to A are reduced to 1.5 times those to B then the travel pattern would change and this person would travel 33 times to A and 67 times to B. Translated to the Hobart context, this means that a person living in Bridgewater might spend most of her time in Bridgewater, because trips to central Hobart are too expensive. The introduction of a new means of transport which makes travel to Hobart less costly would enable this person to go to central Hobart more often. [50]

Table B3 shows the intrinsic attractiveness matrix used in the model. Each number represents the frequency with which a representative customer chooses to visit the attractor shown in the first column under the alternative of visiting the corresponding attractor in the first row. For example, the matrix shows that a person who has the choice between visiting the Centre of Town and North Hobart will visit the Centre in 84 percent of the cases (if the cost of travelling is identical).

Table B3 **Intrinsic attractiveness matrix**

	Centre	North Hobart	Moonah	Glenorchy	Claremont	Rosny Park	Kingston	Sandy Bay	Bridgewater
Centre	100%	84%	94%	89%	97%	95%	95%	51%	97%
North Hobart	16%	100%	75%	62%	86%	80%	79%	39%	74%
Moonah	6%	25%	100%	35%	67%	57%	56%	49%	81%
Glenorchy	11%	38%	65%	100%	79%	71%	70%	55%	85%
Claremont	3%	14%	33%	21%	100%	40%	38%	20%	52%
Rosny Park	5%	20%	43%	29%	60%	100%	48%	63%	88%
Kingston	5%	21%	44%	30%	62%	52%	100%	54%	84%
Sandy Bay	49%	61%	51%	45%	80%	37%	46%	100%	82%
Bridgewater	3%	26%	19%	15%	48%	12%	16%	18%	100%

Data source: DIER

As mentioned above, the intrinsic attractiveness matrix is adjusted according to the relative travel cost for each SA1. Table B4 and Table B5 illustrate this process for one SA1. Table B4 shows the total (minimum) travel cost from this SA1 to each attractor and then compares this value to the cost of travelling to every other attractor. For example the cost of travelling to the Centre is

[50] Given the intrinsic attractiveness of central Hobart is higher than that of Bridgewater. This is the case in the model.

$11.60 and that of travelling to North Hobart is $7.76. This means that for this representative person it is 1.5 time more costly to travel to the Centre than it is to travel to North Hobart. This is turn affects the comparative attractiveness of the two destinations. As shown in Table B5 this person travels to the Centre only in 56 percent of the cases because it is significantly less costly to travel to North Hobart (the intrinsic attractiveness showed a value of 84 percent).

Table B4 **Relative cost matrix**

SA1 no. 6100101	Centre	North Hobart	Moonah	Glenorchy	Claremont	Rosny Park	Kingston	Sandy Bay	Bridgewater
Cost	11.60	7.76	6.19	5.52	4.07	7.07	12.30	8.94	1.04
Relative cost									
Centre	1.00	1.50	1.88	2.10	2.85	1.64	0.94	1.30	11.18
North Hobart		1.00	1.25	1.41	1.91	1.10	0.63	0.87	7.47
Moonah			1.00	1.12	1.52	0.87	0.50	0.69	5.96
Glenorchy				1.00	1.36	0.78	0.45	0.62	5.31
Claremont					1.00	0.58	0.33	0.46	3.92
Rosny Park						1.00	0.58	0.79	6.81
Kingston							1.00	1.38	11.84
Sandy Bay								1.00	8.61
Bridgewater									1.00

Table B5 **Adjusted attractiveness matrix**

SA1 no. 6100101	Centre	North Hobart	Moonah	Glenorchy	Claremont	Rosny Park	Kingston	Sandy Bay	Bridgewater
Centre	100.0%	56.0%	50.1%	42.5%	34.0%	58.2%	100.0%	39.5%	8.7%
North Hobart	44.0%	100.0%	59.8%	44.0%	45.1%	73.0%	100.0%	45.2%	9.9%
Moonah	49.9%	40.2%	100.0%	31.3%	44.2%	65.6%	100.0%	70.2%	13.6%
Glenorchy	57.5%	56.0%	68.7%	100.0%	58.3%	91.4%	100.0%	89.5%	15.9%
Claremont	66.0%	54.9%	55.8%	41.7%	100.0%	68.8%	100.0%	43.0%	13.3%
Rosny Park	41.8%	27.0%	34.4%	8.6%	31.2%	100.0%	84.0%	79.8%	13.0%
Kingston	0.0%	0.0%	0.0%	0.0%	0.0%	16.0%	100.0%	39.5%	7.1%
Sandy Bay	60.5%	54.8%	29.8%	10.5%	57.0%	20.2%	60.5%	100.0%	9.5%
Bridgewater	91.3%	90.1%	86.4%	84.1%	86.7%	87.0%	92.9%	90.5%	100.0%

The final step in this process is to derive an origin-destination-matrix which translates the pairwise attractiveness comparisons shown above into a relative trip frequency from each SA1 to each centre. That is, instead of only comparing to destinations at a time, the origin-destination-matrix provides travel frequencies to all nine destinations at once. This is done using matrix algebra. The resulting frequencies can be interpreted just like the ones in the directed travel simulation, but change for each factor combination. Table B6 shows an excerpt from one realisation of the origin-destination-matrix.

Table B6 **Leisure model origin-destination-matrix (excerpt)**

SA1	Centre	North Hobart	Moonah	Glenorchy	Claremont	Rosny Park	Kingston	Sandy Bay	Bridgewater
6100101	10.1%	10.2%	10.4%	11.7%	13.9%	9.0%	2.7%	10.7%	21.3%
6100102	10.2%	10.2%	10.5%	11.7%	13.9%	9.0%	2.7%	10.8%	21.1%
6100103	10.2%	10.2%	10.5%	11.7%	13.9%	9.1%	2.7%	10.8%	20.9%
6100104	10.1%	10.1%	10.4%	11.7%	13.9%	9.0%	2.7%	10.7%	21.3%
6100105	10.0%	10.1%	10.4%	11.7%	13.9%	8.9%	2.6%	10.7%	21.7%

The calculation of net benefits in the non-directed demand model also works slightly differently to the directed model, and in fact in a manner more similar to a "standard" cost benefit analysis, by considering the average saving for those who switch, rather than calculating a change in consumer surplus.

The issue is the fact that people can switch destinations in the non-directed demand models, which means that, even within a given scenario (before the railway, say), in the random draws where travel costs are high, they might choose a nearby shopping centre, but where travel costs are low, they might choose one further away. The discussion in Appendix B covers this in more detail, but the net result is that several demand curves exist. There are ways to treat this issue empirically, but there are no data on non-directed travel in Hobart that are sufficiently detailed to calibrate the model adequately. We consider that a very sophisticated model which cannot be shown to have any bearing to reality because of a lack of data is not a very good tool for public transport (or indeed any) policymaking, and thus use our simpler approach above.

B.3 Demand functions and the estimation of consumer surplus

The cost functions specify how we estimate the cost of each directed and non-directed trip. In this section we explain how the cost functions are used to estimate demand functions and these in turn are used in the calculation of consumer surplus.

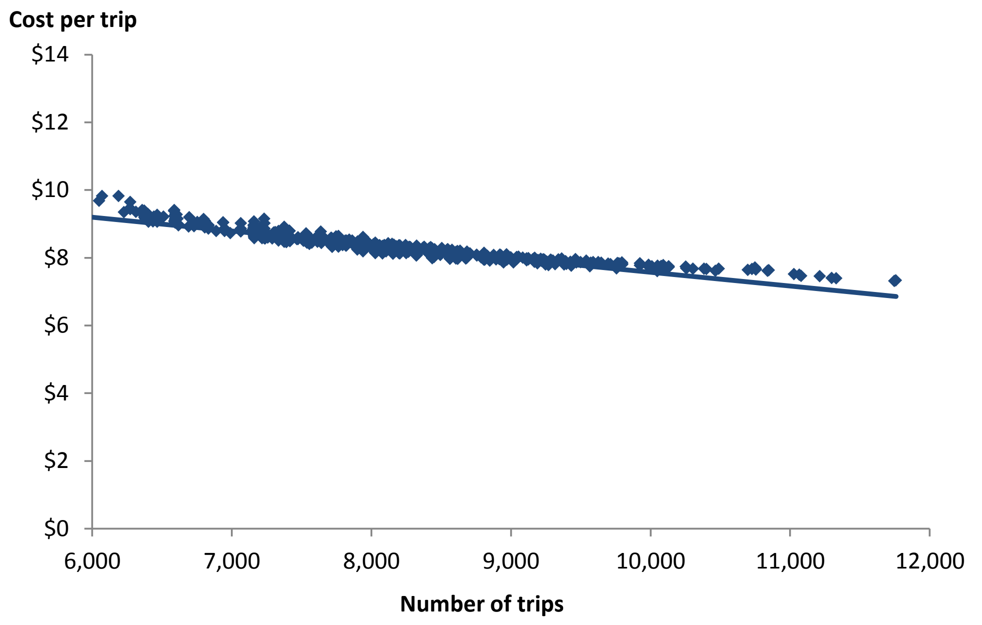
Each cost function has a number of parameters which we allow to vary. These parameters, and the degree to which they vary, are shown in Table B7.

Table B7 **Parameters and their variation in the model**

Variable	Expected value directed	Expected value leisure	Standard deviation
Average speed car outer (km/h)	80.0	90.0	10.0
Average speed car inner (km/h)	40.0	60.0	10.0
Average speed bus (km/h)	33.0	45.0	10.0
Average speed bus inner (km/h)	17.0	30.0	10.0
Average speed feeder (km/h)	33.0	45.0	10.0
Average speed feeder inner (km/h)	22.0	30.0	10.0
Fuel price ($)	1.5	1.5	0.1
Ticket price ($)	3.0 (commuters only)	2.0 (population)	0.1

The process by which the demand curves are derived is as follows. For each SA1, we draw a set of parameters from the list which vary (above) and calculate the cost of each of the five trips, for the directed and non-directed case. We then choose the lowest cost option (one for directed, one for non-directed), and then repeat the process. The result is a scatter plot showing the average travel cost for a work or non-directed trip for the whole range of minimal cost choices for all possible parameter ranges shown in Table B7. An example of such a scatter plot is shown in Figure B2, with the relevant demand curve fitted to it.

Figure B2 **Bus travel scatter plot and fitted demand curve**



Source: ACIL Tasman modelling

We fit a curve to the scatter plot using regression analysis. In order to do so, we need to specify the functional form, and we specify a linear functional form, because this provides the best fit.

The consumer surplus is the area under each demand curve at the prevailing price. It is calculated as the integral between the minimum demand[51] and the expected number of trips minus the product of the expected number of trips and the associated expected cost. The final step is to calculate the change in consumer surplus. This is the sum of the consumer surplus for the each of the post LRS cases minus the sum of the pre LRS cases.

B.4 Calibrating the model

In order to assess the validity of the model predictions, we calibrated its outcomes to actual data. DIER provided us with an analysis of unpublished Metro Tasmania patronage data. The results indicate that there are about 16,000 one way bus trips on a typical day of which about 9,500 are commuter and student trips.

Using the assumptions shown in Table B8 the model reproduces these findings. It predicts a total of 16,450 one way trips per day. This figure is composed of 9,600 commuter trips and 6,850 leisure trips.

Table B8 **Parameter values for model calibration**

Variable	Value	Unit
Average speed car outer	80	km/h
Average speed car inner	40	km/h
Fuel price	1.5	$
Average speed bus outer	33	km/h
Average speed bus inner	17	km/h
Ticket bus	3.0	$
Average speed LRV	32.5	km/h
Ticket LRV	3.0	$
Average speed feeder outer	33	km/h
Average speed feeder inner	22	km/h
Average speed feeder LRV	32.5	km/h
Ticket feeder	3.0	$
Average speed P&R outer	80	km/h
Average speed P&R inner	40	km/h

[51] Minimum demand for buses is not zero, because there are a number of persons who rely on public transport that are not affected by the construction of the light rail system. E.g. a 17 year old student living in Kingston who visits a school in central Hobart will have to take a bus whether there is an LRS or not.

Variable	Value	Unit
Average speed P&R LRV	32.5	km/h
Ticket P&R	3.0	$
Fuel price P&R	1.5	$
Walking speed	5	km/h
Average fuel consumption	0.1	l/km
Value of travel	11.8	$/h
Maximum distance to PT student	0.35	km
Walk from CBD station to CBD	3.39	Minutes
Parking cost in CBD	8.00	$/trip
Perceived cost unit values	Low	Unit
Access weighting (short, medium long walk)	1.2	Multiplier
Wait weighting	1.4	Multiplier
In-vehicle weighting (LRV, bus)	0.75	Multiplier
LRV productivity reduction	0.85	Multiplier
Transfer penalty	0	Minutes
Externalities		
Car (ATC 2006 inflated by CPI)	0.06	Unit
Bus (ATC 2006 inflated by CPI)	0.23	$/km
Train externalities (ATC)	0.001	$/km

Appendix C Travel utility and the productive use of travel time

At the stakeholder workshop on February 7th 2013, the point was made that train journeys are not necessarily "dead-time" whereby people are unable to do anything productive. It was noted that the pervasive use of smart-phones and similar technology mean that trains in particular (buses are more difficult as they generally have a less smooth ride, and being in a car as a driver has obvious limitations for smart-phone use) can be used by commuters as productive time. There is therefore a case for considering this in the context of a benefit-cost assessment. To our knowledge, this has yet to be considered by policymakers in the Australian context.

The relevant literature is a small, but growing field. In a broad sense, there is a literature on the utility of travel itself; a challenge to the accepted notion that travel is "dead-time", and thus reducing the amount of travel always causes a net economic gain. Metz (2008), writing about the "myth" of travel time savings (an early, and rather direct challenge to the orthodox view) and Jain & Lyons (2008) writing about how travel time can be viewed as a "gift" are two key papers in this regard. Many authors have also examined, through surveys, what the optimal time of a commute is; Mohktarian & Salomon (2001) were amongst the first and found that it is around 16 minutes in San Francisco. Others have had similar findings (see, for example, Timmermans & Van Der Waerden, 2008 or Jains & Lyon, 2008), even though the "dead-time" theory should see an optimal commute time of zero. Ory & Mokhtarian (2005) summarise some reasons for these non-zero results, which include travel as a form of transition from home to work and a time for the respondent to have to themselves.

However, from the perspective of this light rail project, it is not the utility of travel per se that is important, but rather the utility of light rail relative to other forms of travel; what people can do in a train that they cannot do on other modes of travel and what utility they gain from doing this. The seminal paper in this regard is from Hensher (1977) who developed a simple model that incorporates both the fact that people might work on the given mode of transport, and that they might not take time saved from making a journey as work, but rather as leisure. Although Hensher himself made calculations of the adjustments required to travel time savings, use of his approach, or variants thereof, were rare until the last decade (see DfT, 2009 for a review of use of this approach by Dutch authorities in the 1980s and 1990s). A key reason for this is a lack of ability, prior to around 15 years ago, to do much effective work on any form of transport; as noted above, ICT has been important in ability of people to work on trains (Lyons & Urry, 2005). Since technology is a key factor, changes in technology ought to be kept in mind by policymakers; working on a train is currently easier than working in a car, but ten years from now, driverless car technology may mean that the converse is true.

Much of the debate around the productive use of travel time that has occurred in the policy sense has been associated with the HS2 high speed rail proposal in the UK (see www.gov.uk/government/organisations/department-for-transport/series/hs2-decision). In that context, the debate has been around how conventional benefits ought to be reduced to account for productive use of travel time. The basic argument is that, if a business traveller spends an hour working on a train at present, and will exchange this for working for 45 minutes in the train and 15 minutes in her office once a high speed rail link is developed, then the relevant saving is the benefits of any extra productivity from being in the office for 15 minutes, rather than on the train, plus any improvements in the trains themselves (say, better wi-fi). This is much less than 15 minutes worth of total work time; the benefit associated with a "conventional" analysis. To the extent that Australian railway studies focus on new links that are faster than existing rail links where people already do work, similar issues would arise.

The context in Hobart is quite different, as there is no existing (passenger) rail link. Instead, we have a situation where people are moving from a mode where they can do little or no productive work, like a car, to one where they may be able to work productively. Thus, if a person swaps a car trip of 12 minutes for a light rail trip of ten minutes, where she can work productively for five of these minutes, a conventional analysis will pick up the clock-time saving of two minutes, but miss the effective time saving of five minutes. Thus, it would under-estimate the total benefits of the rail project. In the report, we subtract the amount of time people might work on the LRVs (on average) from their actual trip time, which is the simplest way in which to capture the "gift" of productive time that comes from being able to access a transport mode which allows productive time to be utilised. We note that, in all likelihood, the train passenger is doing something in the five minutes of non-productive time alluded to above. However, most of the things he or she could be doing (listening to music, looking at the scenery and so on) are things which could also be done on other modes of transport.[52] As such, while the contribution to the utility of travel itself, it is less correct to assert that they are a unique benefit associated with the light rail. The ability to do productive

[52] Some, in fact, have been construed as a response to the disutility of public transport; see for example Skånland (2011) who notes that music is often used to create a sense of personal space on public transport.

work, however, is something which can more convincingly be argued to be unique to trains.

The question now becomes "how many people engage in productive work on trains, and for how long do they do so?". This is not an easy question to answer, as the amount of empirical literature is slight, particularly in the Australian context.[53]

One question which has not been answered with any degree of certainty is how much better rail is compared to other modes for productive work, as almost all of the existing research has been done in regards to trains, rather than being cross-modal. However, Dutch research from the 1980s and 1990s, suggests that less than two per cent of travel time in cars and less than five per cent in buses (as against 11 per cent in trains) was used for productive work (see DfT, 2009, for details). Moreover, it is not difficult to appreciate that undertaking productive work in a car (particularly as a driver) or a bus (with its less smooth ride and greater number of stops) is far less likely than in a train. We therefore assume, for the purposes of our model, that there is no productive work being undertaken by bus or car commuters in Hobart at present, and that the rail is unique in this regard. To the extent that some productive work is being undertaken, this may overstate the benefits of rail, but since we have been rather conservative in our assessments of how much work is likely to be done in the trains, any overstatement is likely to be minimal.

With this caveat in mind, we turn to the findings of the literature, and immediately face three more caveats. The first of these is that cultural context matters. For example, Gripsrud & Hjorthol (2012) examine the relatively high productive time on Norwegian trains, but the fact that Norwegian commuters are often compensated by their employers for work done on the train, while Australian commuters are generally not (as distinct from travel during business hours), means that Norwegian results would overstate likely impacts in Australia. Ohmori & Harata (2008) reporting on the activities of Japanese commuters note the cultural taboo of speaking on the telephone whilst in the train which (sadly!) does not exist in other countries and thus potentially alters both the amount and nature of productive work that might be done on the train in Japan compared to other countries.

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[53] Despite a paucity of research, however, something must be happening. Brisbane trains have begun a roll-out of free wi-fi on trains, Sydney trains have wi-fi on some services (as does the Manly Ferry), Melbourne is planning a roll-out and has free wi-fi in some stations (as well as periodic access on trams, often commercially sponsored), the Labor Party in Perth promised a roll-out of wi-fi on Perth trains if it won the recent election (which it did not) and Adelaide has recently announced a wi-fi trial on its buses. Clearly, people do not use free wi-fi just for productive work, but equally clearly, there is sufficient demand for wi-fi on commuter rail systems for its prevalence to be rising. This provides scope for further research in Australia, following similar lines to research overseas.

A second caveat is that it is not just the fact that a train is available that makes people engage in productive work. Watts (2008) shows that what people bring with them on the train matters; they need to be "equipped" to do productive work, which is becoming easier with ICT advancements. Gripsrud & Hjorthol (2012) show that the characteristics of the train itself matter, particularly characteristics such as comfort, sufficient space and quietness in the train, and timeliness of trains (ie – sticking to their timetable) when planning trips. In particular, the extent to which it is crowded has a significant effect on the amount of work that can be done as does whether the people are sitting or standing (see Ohmori & Harata, 2008).

A third and more important caveat is that most of the empirical literature, with one key exception detailed below, has involved examining train trips that are relatively long; Lyons, et al (2007) shows (in a UK context) 16 percent of those on journeys of between half an hour and one hour do work or study, rising to 20 percent for trips of one to two hours, before falling again to 18 percent for trips of two to three hours and 13 percent for trips beyond three hours. This is quite clearly a different context to the short journey from Glenorchy to Hobart, and is often more akin to the way in which Australian travellers utilise air travel.

With these caveats in mind, we now turn to the empirical evidence concerning how much productive time people spend in trains.

Perhaps the most well-known sources of data are the National Passenger Surveys used in the UK as part of the regulation of train operating companies which, in 2004 and 2010 included questions about use of time on trains, and the Study of the Productive Use of Rail Travel-Time (SPURT) survey, which was commissioned by the Department for Transport in the UK specifically to examine use of time issues in the context of HS2. The former generated some 26,000 responses, and the latter around1,600; far greater than the numbers of observations or survey respondents in most other pieces of work. The National Passenger Survey data is useful also because the same questions were asked at two different points in time (albeit not to the same people; it is not a true panel dataset) allowing investigators to track changes in productive use of time during a period when technological change made people much more well-equipped to work in trains. The National Passenger Survey results are reported in Lyons, Jain & Holley (2007) and Lyons, Jain, Susilo & Atkins (2012), as well as being repeated in submissions to the HS2 review.[54] The SPURT results are reported in DfT (2009) in great detail, but also in other works available from the above URL.

[54] See www.gov.uk/government/organisations/department-for-transport/series/hs2-decision

Lyons et al (2012) show that around 27 percent of those travelling on British trains in their survey were working or studying some of the time during their trip in 2010, and 14 percent were working or studying all of the time. These figures are virtually unchanged from 2004. Most people suggested that the time spent on the train was either very worthwhile (30 percent) or that they made some use of their time on the train (55 percent). Business travellers in particular were significantly less likely to have considered their trip to have been wasted in 2010 compared to 2004, and this was due primarily to quality improvements; satisfaction with train punctuality increased from 15 to 82 percent and with the space available to sit or stand from 59 to 68 percent. This is suggestive of the kinds of quality factors that make work on trains more likely.

Gripsrud & Hjorthol (2012) report on the situation in Norway. While the Lyons et al (2007, 2012) papers above cover journeys of varying lengths, this study focuses on inter-city trains, with the shortest journey being 95 km. Additionally, there is the cultural issue of employers paying commuters for working on the train. In this instance, 27 percent of business travellers and almost a third of commuters use ICT for their entire journey, and half of commuters and 41 percent of business travellers say this makes their journey more worthwhile than it would otherwise be.

Ohmori & Harata (2008) examine the situation in Japan, where commuting by rail is particularly prevalent. They focus in particular on one commute, from Machida to Shinjuku in central Tokyo (a direct service with no stops), and on three different classes of patrons; those who were sitting in "liner trains" (special carriages where they are guaranteed a seat by paying Y400 on top of the fare of Y340). The results highlighting work activities are shown in Table C1 below.

Table C1 **Work activities – Ohmori & Harata**

Activity	Sitting in a liner train	Sitting in a normal train	Standing in a normal train
Reading work documents	27.6%	15.3%	8.5%
Reading newspapers for work	35.3%	35.1%	25.3%
Emailing by mobile phone for work	7.7%	5.4%	4.4%
Web-browsing by mobile phone for work	0.6%	3.6%	4.4%
Using PC/PDA for work	4.5%	4.5%	0
Thinking about work	39.7%	34.2%	15.4%

Data source: Ohmori & Harata (2008). Note that people could do multiple activities, and that passengers did between three and four activities (including many non-work choices not shown).

The paper only provides limited results on how long people were doing each of these tasks, but an earlier observational pilot study following individuals on the same journey in the liner car showed people reading documents for around

20 minutes (2.5 percent of the sample) using a PDA for an average of 11 minutes (1.2 percent of the sample), using a mobile phone for an average of 7.3 minutes (13.1 percent of the sample) or web-browsing for an average of 8.7 minutes (7.1 percent of the sample).[55] This provides some indication of potential effective journey times, albeit in a very different context.

The other useful aspect of the Ohmori & Harata (2008) study is that they asked respondents how much they would be willing to pay for quality enhancements in the liner cars. The results suggested respondents would pay Y127 for a wireless LAN (not present in the trains at the time of the study) and Y366 for a private room, rather than just a seat. Since these passengers had already paid Y400 for the guaranteed seat, and since their ability to do much work (see Table C1 above) was somewhat limited in a normal train, if standing up, one might construe that the price these commuters are willing to pay for the optimal environment suited for work is Y893.[56] This is around 35 percent of their hourly wages, according to the survey results.

The UK SPURT survey (see above) was designed quite specifically to examine the use of time on services likely to be affected by the HS2 high speed rail project in Britain. It thus focuses on inter-city trips, and also on business travellers, rather than commuters. It shows that around 80 percent of business rail travellers work on the train, and that they spend around 57 percent of their time on a given trip, making 46 percent of work-time overall. Moreover, their productivity on the train is almost the same as in the office, at 97 percent. A final important finding is that 13 percent of the journey time for these travellers doing work is spent settling down at the outset of the trip, or getting ready to disembark at the other end; they do not work, in other words, from the time they get into their seats until the time the train stops.

In the context of New Zealand, O'Fallon & Wallis (2012) note that around a fifth of their sample of commuters (who were surveyed; this was not an observational study where the investigator watched people in trains) did some work whilst using public transport.[57] The survey did not ask how long they spent doing work or study on their trip, making it difficult to convert this figure into a "saving of productive time" as outlined above. However, the study did focus on shorter commuter trips.

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55 By contrast, more than two-thirds of those observed slept, for 24.3 minutes on average; a common phenomenon on Japanese trains.

56 Though we note that the respondents would not necessarily be using the higher-quality facilities for work.

57 Russell (2011) reports similar percentages for her NZ study, though she cites Thomas (2009) at only 12.7 percent, but notes that this includes bus and train passengers.

The final study (Gamberini et al, 2013), which again focussed on short trips (on the London Underground), did so specifically to address the question of whether behaviour on short trips was demonstrably different to the longer trips which comprise the bulk of the literature. In this instance, the average trip time was 22.5 minutes, and the time spent in a single carriage was 12.7 minutes. Thus, although the London Underground is a very different transport system to the Hobart Light Rail, the travel times are roughly comparable. The study was, however, observational, rather than a survey of people. Thus, although the study reports around a quarter of people using ICT (49 percent listening or watching media, 50 percent speaking or typing on the phone and one third typing on a PC; clearly people did more than one thing), it does not directly report on whether they are using ICT for work purposes.[58] One final point in regard to this study is worth making. The observers followed people for up to five stops. For the first two stops, passive occupations such as staring out the window dominated, and it was not until one got to journeys of four to five stops that the use of ICTs dominated. Thus, for the very shortest of trips, it seems to be the case that there is insufficient time to take out the equipment needed to do work.

Based on the evidence above, we have assumed that the average commuter is able to productively utilise 15 percent of her time (a little over two minutes) on the journey from Glenorchy to Hobart, or vice versa.[59] This is roughly equivalent to the findings in Britain for Lyons et al (2012), which we note captured much longer journeys in its sample. For journeys starting and ending at stations between Glenorchy and Hobart, we assume no productive work is undertaken, based on the findings of Gamberini et al (2013).

[58] However, the authors cite a survey of Underground users undertaken by a consumer magazine in the UK which showed that 60 percent of people wanted mobile coverage Underground, and that 30 percent of these said they would use it for work purposes.

[59] Or, equivalently, 15 percent of people on the train make use of all of their time productively on the trip; the two are mathematically equivalent.

Appendix D Agglomeration Economies

As noted in the main text, agglomeration economies refer to the additional boost in productivity (and thus income or wealth) associated with increases in density. The fact that productivity and wages are generally higher in cities (and higher in larger than smaller cities) has long been known to economists, and even Adam Smith commented upon the benefits of industrial agglomeration. In the 20th Century, Marshall (1920) spurred a new literature with his comments about knowledge being "in the air" in industrial agglomerations (see Henderson, 1986, Moonow, 1981 and Quigley, 1998 for three reviews of this literature). However, it was Krugman (1991) who put in place a theoretical underpinning for understanding what drives agglomeration economies, giving rise to the field of "new economic geography", and a surge in the theoretical and empirical literature on the "economies of cities" over the past 20 years (see Krugman, 2008, for a reflection of the development of this idea). Krugman (1991) posited a model where a tension between centripedal forces such as agglomeration economies and centrifugal forces such as increasing land prices, higher wage costs and urban social externalities such as crime and pollution, drives the creation and scale of cities. Krugman's (1991) model is based in turn on a model of monopolistic competition devised by Dixt & Stiglitz (1977), a key consideration when discussing agglomeration economies; cities (in the sense of economic theory) exist because of imperfections in market and would not exist in a perfectly competitive world.

Agglomeration economies exist because firms benefit by co-location; each creates positive externalities that others around it are able to harness and benefit from. Glaeser & Gottleib (2009), reflecting on views fairly widespread in the literature, posits three key forces which might give rise to these externalities; reflecting viewpoints in the wider literature:

- Lower transport costs for inputs (iron ore for steel mills, say) or for outputs travelling to markets (the economic rationale for cities like Chicago in the 19th Century as railways massively lowered transport costs).
- Better access to a wider variety of skilled labour, through multiple firms providing a deeper labour market, reducing the likelihood of employees with specialised skills being unemployed if they lose their current jobs, and thus motivating more investment in labour skills.
- Better exchange of ideas between firms as they interact on a daily basis with each other and exchange employees; Marshall's (1920) notion of ideas and trade secrets being "in the air" and the key underpinning of places like Silicon Valley.

All three sources can be important; Western Australia and Queensland benefit from being "close" (in a transport cost sense) to Chinese steel mills located on the coast in China, and a recent article in a special report on competitiveness in America in the *Economist* (March 16th 2013) notes that industrial agglomerations are beginning to re-emerge in parts of the US rust-belt, because of proximity to the Marcellus Shale and its cheap energy, delivered by hydraulic "fracking" and similar recently-developed techniques. However, Glaeser & Kohlhase (2004) makes a case that the transport of goods I a much less important component of overall costs today than it has been in the past, and Glaeser & Gottleib (2009) suggest that this lessens the importance of the first dot-point above.

Underpinning all three notions of agglomeration economies above is the notion of co-location, and thus of distance. Rosenthal & Strange (2004) characterise distance in three dimensions;[60] geographic or physical distance, the degree of similarity between the activities of the relevant firms and the length of time between interactions between firms in the region. Transport quite obviously has a direct influence on the first of these, because it reduces the cost of physical travel and transport, effectively bringing locations closer together. It has a smaller impact on the second two, although firms located closer together are more likely to be in contact with each other.

It is this direct impact which has been of primary interest to policymakers, who seek to understand practical ways in which they might uncover what agglomeration economies a particular transport initiative might create, to aid in the ex-ante decision of whether to fund the project or not. This requires the development of models of agglomeration economies associated with transport; an area where the UK and New Zealand are perhaps most advanced.

Approaches taken in New Zealand and the UK are roughly similar,[61] and thus we describe, in brief, the process as it exists in the UK, closing with a brief description of attempts to extend the approach in Australia. The UK system is part of its Transport Assessment Guidelines (WebTAG – see www.dft.gov.uk/webtag/). The approach begins by estimating the "effective job density" of each sub-region within a given region. This is the number of

[60] And highlight the considerable difficulties in empirically calculating these distances.

[61] We note that Hazeldine, Donovan & Boland (2013) adopt a different approach in the New Zealand context, operationalizing a model from Venables (2007) which solves the employment equilibrium after a transport intervention by accounting for the centripetal forces of higher wages in the centre against the commuting costs associated with reaching jobs there. A transport intervention moves the marginal consumer (the person for whom the increase in wages equals the commuting cost) further out from the centre, increasing the number of employees in the centre and thus creating agglomeration economies. This avoids some of the exogenously-imposed assumptions about labour markets in the current approach.

jobs in each of the other sub-regions, divided by the travel cost to get to each of these other sub-regions; effectively the number of jobs that can be "reached" from each sub-region. If a transport initiative reduces transport costs, this increases the number of jobs which can be reached, and thus the agglomeration effects which might be enjoyed in the destination sub-regions.

The researcher then undertakes an empirical examination of the effect of increasing job density on productivity. That is, she regresses effective job density against data on productivity in different industries and in different sub-regions, with the aim of establishing the relevant elasticity; the extent to which productivity responds to an increase in effective job density. As Graham (2005, 2007) notes, the most common way of doing this is through a translog productivity function,[62] whereby agglomeration economies are taken as having a Hicks-neutral impact on production functions.[63]

The researcher then uses the change in effective job density and the elasticity results to estimate how a transport initiative translates into a productivity effect, and this is converted into an income or wealth effect by multiplying it by the gross regional product of the relevant sub-region.[64]

This kind of analysis is much harder to do effectively in Australia, due to data limitations; the kinds of firm-level data needed for robust results are not available in Australia, at least in public datasets. There have been two responses to this (see Vic DOT, 2012, for a review). The first is to use elasticities from the UK (or New Zealand) in place of calculating them for Australia. This greatly simplifies the analysis, but runs the risk of the elasticities being very different from those which would exist in Australia. The other approach is to attempt to calculate elasticities from the public data that are available in Australia. SGS (2012) and Trubka (2009) represent two recent attempts to do this.

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[62] Earlier studies used Cobb-Douglas or CES production functions; see the table in Graham (2005, p16).

[63] That is, they affect labour and capital equally, without changing their factor proportions. The assumption of Hicks-neutrality is often motivated by reference to a study by Henderson (1986), which assessed agglomeration economies in Brazil and the US, and found evidence of Hicks Neutrality in the Brazilian data (the US data were not tested). Others, however, have found evidence that agglomeration economies may not be Hicks Neutral, and affect capital and labour differently, which would entail a more complex construction of production functions (see, for example, Lall, Shalizi & Deichmann, 2001, and Feser, 2001)

[64] Actually by the gross regional product per worker and the number of employees in each sub-region; GDP figures are rarely disaggregated down to the level of a sub-region of a city.

However, neither approach is particularly successful, when viewed from a technical perspective. In the first instance, the dependent variable is wrong. SGS (2012) use labour productivity which, as Graham (2007) notes means that the effects of capital deepening (more machinery per worker) can be wrongly ascribed to agglomeration economies; the more standard measure used around the world is total factor productivity.[65] Trubka (2009) uses earnings,[66] which has exactly the same problem, even though he wrongly suggests that the use of earnings controls for variation in the use of other factors.

In the second instance, the models are likely to be under-specified. It seems highly unlikely that productivity is a function of a single variable, as both authors suggest. It would be far more standard to at least test for other factors even if it is only through capturing location or time specific factors through a fixed effects model; Du (2011) provides an easily-followed example of accounting for different effects in a Chinese context and Henderson (2003) provides a more sophisticated treatment. In the cases of both SGS (2012) and Trubka (2009), the fact that they have not accounted for capital deepening in their measures of productivity makes it doubly important to examine other causal factors. The effect of under-specifying the model is to over-estimate the relevant elasticity. .

These two issues mean that more work is required in Australia before policymakers have robust numbers for the elasticities between density and productivity comparable to those used in New Zealand and the UK.

Quite apart from these technical modelling issues, however, there are two more fundamental issues which ought to inform policy formed on the basis of a study of agglomeration economies. Moreover, both militate against simply taking the results of a WebTAG-like calculation (regardless of how the elasticities are determined) and adding them to the benefits formed via a more "standard" cost-benefit analysis.

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[65] Where the estimates of total factor productivity take into account the bias from the production function variables and agglomeration economies being correlated with the error terms; see Graham, Gibbons & Martin (2009) for one account of this.

[66] The actual measure is earnings per worker by industry in the relevant region, multiplied by the proportion of workers in that industry Australia-wide. This is done to "control for employment composition" (Trubka, 2009, p4), which he suggests provides a "truer" measure of agglomeration isolated from differences in employment type (ibid, p5). This is simply not true; what actually happens is that, in cases where local employment in a low-wage industry is high relative to the national average, he over-estimates the true local measure of "productivity" and conversely if an area is dominated by high wage jobs. Thus, if a particular area has high wages precisely because of localisation agglomeration (a concentration of workers in a particular industry), the productivity measure will miss this effect. The basic problem is that the model being used is hopelessly under-specified.

The first of these relates to how agglomeration effects are manifest, and the direction of causation by which they are driven. Despite the fact that economists have long observed higher wages in larger cities, and despite the fact that one would be hard-pressed to find an economist who totally disbelieves agglomeration effects are real, empirical evidence clearly identifying the direction of causation has, thus far, proven elusive. It is not clear whether greater population densities have driven up wages, or whether higher wages in a region have attracted more people, or whether some third factor is driving both phenomena. Glaeser & Gottleib (2009; see also Rosenthal & Strange, 2004) summarise attempts to escape this endogeneity trap through the use of instrument variables, and note that, thus far, these attempts have had only mixed effects.

Vic DoT (2012) note in their review that more recent attempts at estimating agglomeration economies, which take into account other potential causal factors like firm selection (only the most productive firms survive in a bigger marketplace) and firm-sorting (firms choose areas attractive to their employees, and only the most highly productive employers can locate in high-amenity areas like the centres of cities), have estimates of agglomeration economies only half the size of earlier estimates. This is similar to the debate about the Solow Residual (See Solow, 1957, and Maddison, 1987, for a comprehensive attempt to "nail down" the residual) in development economics. In that field, the Solow Residual is that which is "left-over" when other potential causal factors have been considered and explored empirically; as more are explored, it shrinks. Agglomeration economies may be going through a similar process of discovery.

This ambiguity about causal factors is important for policymakers, for it means that policy initiatives might not necessarily work; simply changing transport and land use planning policies to favour density levels seen in other cities that have experienced productivity growth does not mean that the city for which plans are being developed will experience the same kinds of productivity growth. This suggests that policymakers seeking to understand agglomeration economies need to take a more nuanced view about what might be driving productivity, particularly if they are looking to other cities as models.

The second issue relates to the type of agglomeration economies which are being experienced. Broadly-speaking, one can divide agglomeration economies into two types; localisation economies (firms in the same industry forming a cluster) and urbanisation economies (a function of city size, not industry composition). The former are sometimes called "Marshallian Agglomeration Economies" after the seminal work of Marshall (1920) who was discussing what we would now term "industrial hubs". The latter are sometimes called

"Jacobs Externalities" after the pioneering work of Jane Jacobs (1961) who studied the vitality of "great" American cities, and made the salient point that it is often through interaction between unlike industries that this vitality is created. Henderson (1986) notes that failing to make the distinction can often mean that localisation economies are mischaracterised as urbanisation economies simply because larger cities tend to have more industry clusters in them. Tellingly, in his examination of US and Brazilian data, he finds much more evidence of localisation than of urbanisation economies. Others make similar findings (see, for example, Henderson, 2003, or Rosenthal & Strange, 2003)

The distinction again matters for policymakers. If the main source of agglomeration economies (either generally or in a particular context) is localisation, then improving transport links is likely to have only a small effect. Industrial policy which provides incentives for groups of like firms to co-locate may be the more successful option; with the caveat that governments have a decidedly mixed record when it comes to industrial policy.

The discussion above highlights why considerable caution ought to be given when assessing estimates of agglomeration economies, and why it is simply wrong to add these economies to the results of a benefit cost analysis. In so doing, we support the stance of IA in requiring a separate analysis, and would add that such an analysis would need to couch any findings in the context of the shortcomings outlined above, and provide specific reference as to how those shortcomings play out in the particular context being analysed. The report by Vic DoT (2012) is exemplary in this regard, highlighting clearly the benefits and pitfalls of estimating agglomeration economies.

Our purpose in this report is to undertake a "standard" benefit-cost analysis, and not to estimate agglomeration economies from the proposed railway. However, we do consider it worthwhile to undertake a relatively simple, broad-brush estimate of likely agglomeration economies. We make use of ABS data on employment by SA1 in Hobart (from the recent Census) and the findings of our model in terms of travel-time before and after the development of the railway.[67] We aggregate regions outside our core study area in the same way we have done so for the demand model. We then implement equations 2.3 and 2.1 from WebTAG (2012; p4-6) showing respectively the effective job density and the impact of agglomeration economies. We supress the disaggregation into industries, and use averages across industries for SA1's for simplicity, and

[67] Unlike SGS (2012), but like WebTAG, we do not split and just consider the change in travel costs for all consumers in each SA1 in our sample. In this manner, we pick up how the railway affects everyone, not just those who ride upon it.

we make use of the elasticities used in WebTAG in light of the lack of robust Australian estimates. We acknowledge that this is likely to over-estimate the agglomeration economies because the UK is a very different context to Hobart, and point out that our findings should be interpreted as upper bounds of likely results. In this context, they provide policymakers with guidance as to whether the impacts are large enough that refining estimates would be cost effective.

Appendix E Proposed LRS Timetable

Proposed timetables for the four OOSMs are presented in the figures below.

Figure E1 **OOSM1 indicative proposed timetable**

OPTIMAL OPERATING SERVICE MODEL 1 (ILLUSTRATIVE TIMETABLE ONLY)

Three station Fast system

INBOUND: GLENORCHY > MOONAH > HOBART ELIZABETH ST (FRANKLIN SQUARE)

Monday to Friday

	am	am	am	am	am	am	am	am	am	am	am
Glenorchy	6:01	6:31	7:01	7:16	7:31	7:46	8:01	8:16	8:31	8:46	9:01
Moonah	6:04	6:34	7:04	7:20	7:35	7:50	8:05	8:20	8:35	8:50	9:05
Hobart Elizabeth St	6:15	6:46	7:16	7:32	7:47	8:02	8:17	8:32	8:47	9:02	9:17
	am	am	am	am	am	am	am	am	am	am	am
Glenorchy	9:16	9:31	9:46	10:01	10:16	10:31	10:46	11:01	11:16	11:31	11:46
Moonah	9:20	9:35	9:50	10:05	10:20	10:35	10:50	11:05	11:20	11:35	11:50
Hobart Elizabeth St	9:32	9:47	10:02	10:17	10:32	10:47	11:02	11:17	11:32	11:47	12:02
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Glenorchy	12:01	12:16	12:31	12:46	13:01	13:16	13:31	13:46	14:01	14:16	14:31
Moonah	12:05	12:20	12:35	12:50	13:05	13:20	13:35	13:50	14:05	14:20	14:35
Hobart Elizabeth St	12:17	12:32	12:47	13:02	13:17	13:32	13:47	14:02	14:17	14:32	14:47
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Glenorchy	14:46	15:01	15:16	15:31	15:46	16:01	16:16	16:31	16:46	17:01	17:16
Moonah	14:50	15:05	15:20	15:35	15:50	16:05	16:20	16:35	16:50	17:05	17:20
Hobart Elizabeth St	15:02	15:17	15:32	15:47	16:02	16:17	16:32	16:47	17:02	17:17	17:32
	pm	pm	pm	pm	pm	pm					
Glenorchy	17:31	17:46	18:01	18:31	19:01	19:31					
Moonah	17:35	17:50	18:05	18:34	19:04	19:34					
Hobart Elizabeth St	17:47	18:02	18:17	18:46	19:16	19:46					

Saturday

	am	am	am	am	am	am	am	am	pm	pm	pm
Glenorchy	8:01	8:31	9:01	9:31	10:01	10:31	11:01	11:31	12:01	12:31	13:01
Moonah	8:04	8:35	9:05	9:35	10:05	10:35	11:05	11:35	12:05	12:35	13:05
Hobart Elizabeth St	8:15	8:46	9:16	9:46	10:16	10:46	11:16	11:46	12:16	12:46	13:16
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Glenorchy	13:31	14:01	14:31	15:01	15:31	16:01	16:31	17:01	17:31	18:01	18:31
Moonah	13:35	14:05	14:35	15:05	15:35	16:05	16:35	17:05	17:35	18:05	18:35
Hobart Elizabeth St	13:46	14:16	14:46	15:16	15:46	16:16	16:46	17:16	17:46	18:16	18:46
	pm										
Glenorchy	19:01										
Moonah	19:04										
Hobart Elizabeth St	19:16										

Sunday and Public Holidays

	am	am	am	am	am	am	am	pm	pm	pm	pm
Glenorchy	9:01	9:31	10:01	10:31	11:01	11:31	12:01	12:31	13:01	13:31	14:01
Moonah	9:05	9:35	10:05	10:35	11:05	11:35	12:05	12:35	13:05	13:35	14:05
Hobart Elizabeth St	9:15	9:46	10:16	10:46	11:16	11:46	12:16	12:46	13:16	13:46	14:16
	pm	pm	pm	pm	pm	pm	pm	pm			
Glenorchy	14:31	15:01	15:31	16:01	16:31	17:01	17:31	18:01			
Moonah	14:35	15:05	15:35	16:05	16:35	17:05	17:35	18:05			
Hobart Elizabeth St	14:46	15:16	15:46	16:16	16:46	17:16	17:46	18:16			

OUTBOUND: HOBART ELIZABETH ST (FRANKLIN SQUARE) > MOONAH > GLENORCHY

Monday to Friday

	am	am	am	am	am	am	am	am	am	am	am
Hobart Elizabeth St	6:23	6:53	7:23	7:38	7:53	8:08	8:23	8:38	8:53	9:08	9:23
Moonah	6:34	7:04	7:35	7:50	8:05	8:20	8:35	8:50	9:05	9:20	9:35
Glenorchy	6:38	7:08	7:39	7:54	8:09	8:24	8:39	8:54	9:09	9:24	9:39
	am	am	am	am	am	am	am	am	pm	pm	pm
Hobart Elizabeth St	9:38	9:53	10:08	10:23	10:38	10:53	11:08	11:23	11:38	11:53	12:08
Moonah	9:50	10:05	10:20	10:35	10:50	11:05	11:20	11:35	11:50	12:05	12:20
Glenorchy	9:54	10:09	10:24	10:39	10:54	11:09	11:24	11:39	11:54	12:09	12:24
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	12:23	12:38	12:53	13:08	13:23	13:38	13:53	14:08	14:23	14:38	14:53
Moonah	12:35	12:50	13:05	13:20	13:35	13:50	14:05	14:20	14:35	14:50	15:05
Glenorchy	12:39	12:54	13:09	13:24	13:39	13:54	14:09	14:24	14:39	14:54	15:09
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	15:08	15:23	15:38	15:53	16:08	16:23	16:38	16:53	17:08	17:23	17:38
Moonah	15:20	15:35	15:50	16:05	16:20	16:35	16:50	17:05	17:20	17:35	17:50
Glenorchy	15:24	15:39	15:54	16:09	16:24	16:39	16:54	17:09	17:24	17:39	17:54
	pm	pm	pm	pm	pm	pm					
Hobart Elizabeth St	17:53	18:08	18:23	18:53	19:23	19:53					
Moonah	18:05	18:20	18:34	19:04	19:34	20:03					
Glenorchy	18:09	18:24	18:38	19:08	19:38	20:07					

Saturday

	am	am	am	am	am	am	pm	pm	pm	pm	pm
Hobart Elizabeth St	8:24	8:54	9:24	9:54	10:24	10:54	11:24	11:54	12:24	12:54	13:24
Moonah	8:35	9:05	9:35	10:05	10:35	11:05	11:35	12:05	12:35	13:05	13:35
Glenorchy	8:39	9:09	9:39	10:09	10:39	11:09	11:39	12:09	12:39	13:09	13:39
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	13:54	14:24	14:54	15:24	15:54	16:24	16:54	17:24	17:54	18:24	18:54
Moonah	14:05	14:35	15:05	15:35	16:05	16:35	17:05	17:35	18:05	18:35	19:05
Glenorchy	14:09	14:39	15:09	15:39	16:09	16:39	17:09	17:39	18:09	18:39	19:09
	pm										
Hobart Elizabeth St	19:24										
Moonah	19:34										
Glenorchy	19:38										

Sunday and Public Holidays

	am	am	am	am	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	9:24	9:54	10:24	10:54	11:24	11:54	12:24	12:54	13:24	13:54	14:24
Moonah	9:35	10:05	10:35	11:05	11:35	12:05	12:35	13:05	13:35	14:05	14:35
Glenorchy	9:39	10:09	10:39	11:09	11:39	12:09	12:39	13:09	13:39	14:09	14:39
	pm	pm	pm	pm	pm	pm	pm	pm			
Hobart Elizabeth St	14:54	15:24	15:54	16:24	16:54	17:24	17:54	18:24			
Moonah	15:05	15:35	16:05	16:35	17:05	17:35	18:05	18:34			
Glenorchy	15:09	15:39	16:09	16:39	17:09	17:39	18:09	18:38			

Source: DIER

Figure E2 **OOSM 2 indicative proposed timetable**

OPTIMAL OPERATING SERVICE MODEL 2 (ILLUSTRATIVE TIMETABLE ONLY)

Four station Northern Focus

INBOUND: GLENORCHY > DERWENT PARK > MOONAH > HOBART ELIZABETH ST (FRANKLIN SQUARE)

Monday to Friday

	am	am	am	am	am	am	am	am	am	am	am
Glenorchy	6:01	6:31	7:01	7:16	7:31	7:46	8:01	8:16	8:31	8:46	9:01
Derwent Park	6:03	6:33	7:03	7:18	7:33	7:48	8:03	8:18	8:33	8:48	9:03
Moonah	6:05	6:36	7:06	7:21	7:36	7:51	8:06	8:21	8:36	8:51	9:06
Hobart Elizabeth St	6:15	6:47	7:17	7:32	7:48	8:03	8:18	8:33	8:48	9:03	9:18
	am	am	am	am	am	am	am	am	am	am	am
Glenorchy	9:16	9:31	9:46	10:01	10:16	10:31	10:46	11:01	11:16	11:31	11:46
Derwent Park	9:18	9:33	9:48	10:03	10:18	10:33	10:48	11:03	11:18	11:33	11:48
Moonah	9:21	9:36	9:51	10:06	10:21	10:36	10:51	11:06	11:21	11:36	11:51
Hobart Elizabeth St	9:33	9:48	10:03	10:18	10:33	10:48	11:03	11:18	11:33	11:48	12:03
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Glenorchy	12:01	12:16	12:31	12:46	13:01	13:16	13:31	13:46	14:01	14:16	14:31
Derwent Park	12:03	12:18	12:33	12:48	13:03	13:18	13:33	13:48	14:03	14:18	14:33
Moonah	12:06	12:21	12:36	12:51	13:06	13:21	13:36	13:51	14:06	14:21	14:36
Hobart Elizabeth St	12:18	12:33	12:48	13:03	13:18	13:33	13:48	14:03	14:18	14:33	14:48
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Glenorchy	14:46	15:01	15:16	15:31	15:46	16:01	16:16	16:31	16:46	17:01	17:16
Derwent Park	14:48	15:03	15:18	15:33	15:48	16:03	16:18	16:33	16:48	17:03	17:18
Moonah	14:51	15:06	15:21	15:36	15:51	16:06	16:21	16:36	16:51	17:06	17:21
Hobart Elizabeth St	15:03	15:18	15:33	15:48	16:03	16:18	16:33	16:48	17:03	17:18	17:33
	pm	pm	pm	pm	pm	pm					
Glenorchy	17:31	17:46	18:01	18:31	19:01	19:31					
Derwent Park	17:33	17:48	18:03	18:33	19:03	19:33					
Moonah	17:36	17:51	18:06	18:36	19:06	19:35					
Hobart Elizabeth St	17:48	18:03	18:18	18:47	19:17	19:45					

Saturday

	am	am	am	am	am	am	am	am	pm	pm	pm
Glenorchy	8:01	8:31	9:01	9:31	10:01	10:31	11:01	11:31	12:01	12:31	13:01
Derwent Park	8:03	8:33	9:03	9:33	10:03	10:33	11:03	11:33	12:03	12:33	13:03
Moonah	8:05	8:36	9:06	9:36	10:06	10:36	11:06	11:36	12:06	12:36	13:06
Hobart Elizabeth St	8:15	8:47	9:17	9:47	10:17	10:47	11:17	11:47	12:17	12:47	13:17
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Glenorchy	13:31	14:01	14:31	15:01	15:31	16:01	16:31	17:01	17:31	18:01	18:31
Derwent Park	13:33	14:03	14:33	15:03	15:33	16:03	16:33	17:03	17:33	18:03	18:33
Moonah	13:36	14:06	14:36	15:06	15:36	16:06	16:36	17:06	17:36	18:06	18:36
Hobart Elizabeth St	13:47	14:17	14:47	15:17	15:47	16:17	16:47	17:17	17:47	18:17	18:47
	pm										
Glenorchy	19:01										
Derwent Park	19:03										
Moonah	19:06										
Hobart Elizabeth St	19:17										

Sunday and Public Holidays

	am	am	am	am	am	am	am	pm	pm	pm	pm
Glenorchy	9:01	9:31	10:01	10:31	11:01	11:31	12:01	12:31	13:01	13:31	14:01
Derwent Park	9:03	9:33	10:03	10:33	11:03	11:33	12:03	12:33	13:03	13:33	14:03
Moonah	9:05	9:36	10:06	10:36	11:06	11:36	12:06	12:36	13:06	13:36	14:06
Hobart Elizabeth St	9:15	9:47	10:17	10:47	11:17	11:47	12:17	12:47	13:17	13:47	14:17
	pm	pm	pm	pm	pm	pm	pm	pm			
Glenorchy	14:31	15:01	15:31	16:01	16:31	17:01	17:31	18:01			
Derwent Park	14:33	15:03	15:33	16:03	16:33	17:03	17:33	18:03			
Moonah	14:36	15:06	15:36	16:06	16:36	17:06	17:36	18:06			
Hobart Elizabeth St	14:47	15:17	15:47	16:17	16:47	17:17	17:47	18:17			

OUTBOUND: HOBART ELIZABETH ST (FRANKLIN SQUARE) > MOONAH > DERWENT PARK > GLENORCHY

Monday to Friday

	am	am	am	am	am	am	am	am	am	am	am
Hobart Elizabeth St	6:24	6:54	7:24	7:39	7:54	8:09	8:24	8:39	8:54	9:09	9:24
Moonah	6:36	7:06	7:36	7:51	8:06	8:21	8:36	8:51	9:06	9:21	9:36
Derwent Park	6:39	7:09	7:39	7:54	8:09	8:24	8:39	8:54	9:09	9:24	9:39
Glenorchy	6:41	7:11	7:41	7:56	8:11	8:26	8:41	8:56	9:11	9:26	9:41
	am	am	am	am	am	am	am	am	pm	pm	pm
Hobart Elizabeth St	9:39	9:54	10:09	10:24	10:39	10:54	11:09	11:24	11:39	11:54	12:09
Moonah	9:51	10:06	10:21	10:36	10:51	11:06	11:21	11:36	11:51	12:06	12:21
Derwent Park	9:54	10:09	10:24	10:39	10:54	11:09	11:24	11:39	11:54	12:09	12:24
Glenorchy	9:56	10:11	10:26	10:41	10:56	11:11	11:26	11:41	11:56	12:11	12:26
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	12:24	12:39	12:54	13:09	13:24	13:39	13:54	14:09	14:24	14:39	14:54
Moonah	12:36	12:51	13:06	13:21	13:36	13:51	14:06	14:21	14:36	14:51	15:06
Derwent Park	12:39	12:54	13:09	13:24	13:39	13:54	14:09	14:24	14:39	14:54	15:09
Glenorchy	12:41	12:56	13:11	13:26	13:41	13:56	14:11	14:26	14:41	14:56	15:11
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	15:09	15:24	15:39	15:54	16:09	16:24	16:39	16:54	17:09	17:24	17:39
Moonah	15:21	15:36	15:51	16:06	16:21	16:36	16:51	17:06	17:21	17:36	17:51
Derwent Park	15:24	15:39	15:54	16:09	16:24	16:39	16:54	17:09	17:24	17:39	17:54
Glenorchy	15:26	15:41	15:56	16:11	16:26	16:41	16:56	17:11	17:26	17:41	17:56
	pm	pm	pm	pm	pm	pm					
Hobart Elizabeth St	17:54	18:09	18:24	18:54	19:24	19:54					
Moonah	18:06	18:21	18:36	19:06	19:35	20:04					
Derwent Park	18:09	18:24	18:39	19:09	19:38	20:06					
Glenorchy	18:11	18:26	18:41	19:11	19:40	20:08					

Saturday

	am	am	am	am	am	am	am	am	pm	pm	pm
Hobart Elizabeth St	8:25	8:55	9:25	9:55	10:25	10:55	11:25	11:55	12:25	12:55	13:25
Moonah	8:36	9:06	9:36	10:06	10:36	11:06	11:36	12:06	12:36	13:06	13:36
Derwent Park	8:39	9:09	9:39	10:09	10:39	11:09	11:39	12:09	12:39	13:09	13:39
Glenorchy	8:41	9:11	9:41	10:11	10:41	11:11	11:41	12:11	12:41	13:11	13:41
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	13:55	14:25	14:55	15:25	15:55	16:25	16:55	17:25	17:55	18:25	18:55
Moonah	14:06	14:36	15:06	15:36	16:06	16:36	17:06	17:36	18:06	18:36	19:06
Derwent Park	14:09	14:39	15:09	15:39	16:09	16:39	17:09	17:39	18:09	18:39	19:09
Glenorchy	14:11	14:41	15:11	15:41	16:11	16:41	17:11	17:41	18:11	18:41	19:11
	pm										
Hobart Elizabeth St	19:25										
Moonah	19:35										
Derwent Park	19:37										
Glenorchy	19:39										

Sunday and Public Holidays

	am	am	am	am	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	9:25	9:55	10:25	10:55	11:25	11:55	12:25	12:55	13:25	13:55	14:25
Moonah	9:36	10:06	10:36	11:06	11:36	12:06	12:36	13:06	13:36	14:06	14:36
Derwent Park	9:39	10:09	10:39	11:09	11:39	12:09	12:39	13:09	13:39	14:09	14:39
Glenorchy	9:41	10:11	10:41	11:11	11:41	12:11	12:41	13:11	13:41	14:11	14:41
	pm	pm	pm	pm	pm	pm	pm	pm			
Hobart Elizabeth St	14:55	15:25	15:55	16:25	16:55	17:25	17:55	18:25			
Moonah	15:06	15:36	16:06	16:36	17:06	17:36	18:06	18:35			
Derwent Park	15:09	15:39	16:09	16:39	17:09	17:39	18:09	18:38			
Glenorchy	15:11	15:41	16:11	16:41	17:11	17:41	18:11	18:39			

Source: DIER

Figure E3 **OOSM 3 indicative proposed timetable**

OPTIMAL OPERATING SERVICE MODEL 3 (ILLUSTRATIVE TIMETABLE ONLY)

Five station Suburban Focus

INBOUND: GLENORCHY > DERWENT PARK > MOONAH > NEW TOWN > HOBART ELIZABETH ST (FRANKLIN SQUARE)

Monday to Friday

	am	am	am	am	am	am	am	am	am	am	am
Glenorchy	6:01	6:31	7:01	7:16	7:31	7:46	8:01	8:16	8:31	8:46	9:01
Derwent Park	6:03	6:33	7:03	7:18	7:33	7:48	8:03	8:18	8:33	8:48	9:03
Moonah	6:05	6:36	7:06	7:21	7:36	7:51	8:06	8:21	8:36	8:51	9:06
New Town	6:07	6:39	7:09	7:24	7:39	7:54	8:09	8:24	8:39	8:54	9:09
Hobart Elizabeth St	6:16	6:48	7:18	7:33	7:49	8:04	8:19	8:34	8:49	9:04	9:19

	am	am	am	am	am	am	am	am	am	am	am
Glenorchy	9:16	9:31	9:46	10:01	10:16	10:31	10:46	11:01	11:16	11:31	11:46
Derwent Park	9:18	9:33	9:48	10:03	10:18	10:33	10:48	11:03	11:18	11:33	11:48
Moonah	9:21	9:36	9:51	10:06	10:21	10:36	10:51	11:06	11:21	11:36	11:51
New Town	9:24	9:39	9:54	10:09	10:24	10:39	10:54	11:09	11:24	11:39	11:54
Hobart Elizabeth St	9:34	9:49	10:04	10:19	10:34	10:49	11:04	11:19	11:34	11:49	12:04

	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Glenorchy	12:01	12:16	12:31	12:46	13:01	13:16	13:31	13:46	14:01	14:16	14:31
Derwent Park	12:03	12:18	12:33	12:48	13:03	13:18	13:33	13:48	14:03	14:18	14:33
Moonah	12:06	12:21	12:36	12:51	13:06	13:21	13:36	13:51	14:06	14:21	14:36
New Town	12:09	12:24	12:39	12:54	13:09	13:24	13:39	13:54	14:09	14:24	14:39
Hobart Elizabeth St	12:19	12:34	12:49	13:04	13:19	13:34	13:49	14:04	14:19	14:34	14:49

	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Glenorchy	14:46	15:01	15:16	15:31	15:46	16:01	16:16	16:31	16:46	17:01	17:16
Derwent Park	14:48	15:03	15:18	15:33	15:48	16:03	16:18	16:33	16:48	17:03	17:18
Moonah	14:51	15:06	15:21	15:36	15:51	16:06	16:21	16:36	16:51	17:06	17:21
New Town	14:54	15:09	15:24	15:39	15:54	16:09	16:24	16:39	16:54	17:09	17:24
Hobart Elizabeth St	15:04	15:19	15:34	15:49	16:04	16:19	16:34	16:49	17:04	17:19	17:34

	pm	pm	pm	pm	pm	pm
Glenorchy	17:31	17:46	18:01	18:31	19:01	19:31
Derwent Park	17:33	17:48	18:03	18:33	19:03	19:33
Moonah	17:36	17:51	18:06	18:36	19:06	19:36
New Town	17:39	17:54	18:09	18:39	19:09	19:39
Hobart Elizabeth St	17:49	18:04	18:19	18:48	19:18	19:48

Saturday

	am	am	am	am	am	am	am	am	pm	pm	pm
Glenorchy	8:01	8:31	9:01	9:31	10:01	10:31	11:01	11:31	12:01	12:31	13:01
Derwent Park	8:03	8:33	9:03	9:33	10:03	10:33	11:03	11:33	12:03	12:33	13:03
Moonah	8:05	8:36	9:06	9:36	10:06	10:36	11:06	11:36	12:06	12:36	13:06
New Town	8:07	8:39	9:09	9:39	10:09	10:39	11:09	11:39	12:09	12:39	13:09
Hobart Elizabeth St	8:16	8:48	9:18	9:48	10:18	10:48	11:18	11:48	12:18	12:48	13:18

	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Glenorchy	13:31	14:01	14:31	15:01	15:31	16:01	16:31	17:01	17:31	18:01	18:31
Derwent Park	13:33	14:03	14:33	15:03	15:33	16:03	16:33	17:03	17:33	18:03	18:33
Moonah	13:36	14:06	14:36	15:06	15:36	16:06	16:36	17:06	17:36	18:06	18:36
New Town	13:39	14:09	14:39	15:09	15:39	16:09	16:39	17:09	17:39	18:09	18:39
Hobart Elizabeth St	13:48	14:18	14:48	15:18	15:48	16:18	16:48	17:18	17:48	18:18	18:48

	pm
Glenorchy	19:01
Derwent Park	19:03
Moonah	19:06
New Town	19:09
Hobart Elizabeth St	19:18

Sunday and Public Holidays

	am	am	am	am	am	am	pm	pm	pm	pm	pm
Glenorchy	9:01	9:31	10:01	10:31	11:01	11:31	12:01	12:31	13:01	13:31	14:01
Derwent Park	9:03	9:33	10:03	10:33	11:03	11:33	12:03	12:33	13:03	13:33	14:03
Moonah	9:05	9:36	10:06	10:36	11:06	11:36	12:06	12:36	13:06	13:36	14:06
New Town	9:07	9:39	10:09	10:39	11:09	11:39	12:09	12:39	13:09	13:39	14:09
Hobart Elizabeth St	9:16	9:48	10:18	10:48	11:18	11:48	12:18	12:48	13:18	13:48	14:18

	pm	pm	pm	pm	pm	pm	pm	pm
Glenorchy	14:31	15:01	15:31	16:01	16:31	17:01	17:31	18:01
Derwent Park	14:33	15:03	15:33	16:03	16:33	17:03	17:33	18:03
Moonah	14:36	15:06	15:36	16:06	16:36	17:06	17:36	18:06
New Town	14:39	15:09	15:39	16:09	16:39	17:09	17:39	18:09
Hobart Elizabeth St	14:48	15:18	15:48	16:18	16:48	17:18	17:48	18:18

OUTBOUND: HOBART ELIZABETH ST (FRANKLIN SQUARE) > NEW TOWN > MOONAH > DERWENT PARK > GLENORCHY

Monday to Friday

	am	am	am	am	am	am	am	am	am	am	am
Hobart Elizabeth St	6:23	6:53	7:23	7:38	7:53	8:08	8:23	8:38	8:53	9:08	9:23
New Town	6:33	7:03	7:33	7:48	8:03	8:18	8:33	8:48	9:03	9:18	9:33
Moonah	6:36	7:06	7:36	7:51	8:06	8:21	8:36	8:51	9:06	9:21	9:36
Derwent Park	6:39	7:09	7:39	7:54	8:09	8:24	8:39	8:54	9:09	9:24	9:39
Glenorchy	6:41	7:11	7:41	7:56	8:11	8:26	8:41	8:56	9:11	9:26	9:41

	am	am	am	am	am	am	am	am	pm	pm	pm
Hobart Elizabeth St	9:38	9:53	10:08	10:23	10:38	10:53	11:08	11:23	11:38	11:53	12:08
New Town	9:48	10:03	10:18	10:33	10:48	11:03	11:18	11:33	11:48	12:03	12:18
Moonah	9:51	10:06	10:21	10:36	10:51	11:06	11:21	11:36	11:51	12:06	12:21
Derwent Park	9:54	10:09	10:24	10:39	10:54	11:09	11:24	11:39	11:54	12:09	12:24
Glenorchy	9:56	10:11	10:26	10:41	10:56	11:11	11:26	11:41	11:56	12:11	12:26

	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	12:23	12:38	12:53	13:08	13:23	13:38	13:53	14:08	14:23	14:38	14:53
New Town	12:33	12:48	13:03	13:18	13:33	13:48	14:03	14:18	14:33	14:48	15:03
Moonah	12:36	12:51	13:06	13:21	13:36	13:51	14:06	14:21	14:36	14:51	15:06
Derwent Park	12:39	12:54	13:09	13:24	13:39	13:54	14:09	14:24	14:39	14:54	15:09
Glenorchy	12:41	12:56	13:11	13:26	13:41	13:56	14:11	14:26	14:41	14:56	15:11

	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	15:08	15:23	15:38	15:53	16:08	16:23	16:38	16:53	17:08	17:23	17:38
New Town	15:18	15:33	15:48	16:03	16:18	16:33	16:48	17:03	17:18	17:33	17:48
Moonah	15:21	15:36	15:51	16:06	16:21	16:36	16:51	17:06	17:21	17:36	17:51
Derwent Park	15:24	15:39	15:54	16:09	16:24	16:39	16:54	17:09	17:24	17:39	17:54
Glenorchy	15:26	15:41	15:56	16:11	16:26	16:41	16:56	17:11	17:26	17:41	17:56

	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	17:53	18:08	18:23	18:53	19:23	19:53
New Town	18:03	18:18	18:33	19:03	19:33	20:02
Moonah	18:06	18:21	18:36	19:06	19:36	20:04
Derwent Park	18:09	18:24	18:39	19:09	19:39	20:06
Glenorchy	18:11	18:26	18:41	19:11	19:41	20:08

Saturday

	am	am	am	am	am	am	pm	pm	pm	pm	pm
Hobart Elizabeth St	8:24	8:54	9:24	9:54	10:24	10:54	11:24	11:54	12:24	12:54	13:24
New Town	8:33	9:03	9:33	10:03	10:33	11:03	11:33	12:03	12:33	13:03	13:33
Moonah	8:36	9:06	9:36	10:06	10:36	11:06	11:36	12:06	12:36	13:06	13:36
Derwent Park	8:39	9:09	9:39	10:09	10:39	11:09	11:39	12:09	12:39	13:09	13:39
Glenorchy	8:41	9:11	9:41	10:11	10:41	11:11	11:41	12:11	12:41	13:11	13:41

	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	13:54	14:24	14:54	15:24	15:54	16:24	16:54	17:24	17:54	18:24	18:54
New Town	14:03	14:33	15:03	15:33	16:03	16:33	17:03	17:33	18:03	18:33	19:03
Moonah	14:06	14:36	15:06	15:36	16:06	16:36	17:06	17:36	18:06	18:36	19:06
Derwent Park	14:09	14:39	15:09	15:39	16:09	16:39	17:09	17:39	18:09	18:39	19:09
Glenorchy	14:11	14:41	15:11	15:41	16:11	16:41	17:11	17:41	18:11	18:41	19:11

	pm
Hobart Elizabeth St	19:24
New Town	19:33
Moonah	19:35
Derwent Park	19:37
Glenorchy	19:39

Sunday and Public Holidays

	am	am	am	am	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	9:24	9:54	10:24	10:54	11:24	11:54	12:24	12:54	13:24	13:54	14:24
New Town	9:33	10:03	10:33	11:03	11:33	12:03	12:33	13:03	13:33	14:03	14:33
Moonah	9:36	10:06	10:36	11:06	11:36	12:06	12:36	13:06	13:36	14:06	14:36
Derwent Park	9:39	10:09	10:39	11:09	11:39	12:09	12:39	13:09	13:39	14:09	14:39
Glenorchy	9:41	10:11	10:41	11:11	11:41	12:11	12:41	13:11	13:41	14:11	14:41

	pm	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	14:54	15:24	15:54	16:24	16:54	17:24	17:54	18:24
New Town	15:03	15:33	16:03	16:33	17:03	17:33	18:03	18:33
Moonah	15:06	15:36	16:06	16:36	17:06	17:36	18:06	18:35
Derwent Park	15:09	15:39	16:09	16:39	17:09	17:39	18:09	18:37
Glenorchy	15:11	15:41	16:11	16:41	17:11	17:41	18:11	19:39

Source: DIER

Figure E4 **OOSM 4 indicative proposed timetable - weekdays**

OPTIMAL OPERATING SERVICE MODEL 4 (ILLUSTRATIVE AND INDICATIVE TIMETABLE ONLY)

Six Station High Access Focus

INBOUND: GLENORCHY > DERWENT PARK > MOONAH > NEW TOWN > MACQUARIE POINT > ELIZABETH ST (FRANKLIN SQUARE)

Monday to Friday

	am	am	am	am	am	am	am	am	am	am	am
Glenorchy	6:01	6:31	7:01	7:16	7:31	7:46	8:01	8:16	8:31	8:46	9:01
Derwent Park	6:03	6:33	7:03	7:18	7:33	7:48	8:03	8:18	8:33	8:48	9:03
Moonah	6:05	6:36	7:06	7:21	7:36	7:51	8:06	8:21	8:36	8:51	9:06
New Town	6:07	6:39	7:09	7:24	7:39	7:54	8:09	8:24	8:39	8:54	9:09
Macquarie Point	6:14	6:47	7:17	7:32	7:48	8:03	8:18	8:33	8:48	9:03	9:18
Hobart Elizabeth St	6:16	6:49	7:19	7:34	7:50	8:05	8:20	8:35	8:50	9:05	9:20

	am	am	am	am	am	am	am	am	am	am	am
Glenorchy	9:16	9:31	9:46	10:01	10:16	10:31	10:46	11:01	11:16	11:31	11:46
Derwent Park	9:18	9:33	9:48	10:03	10:18	10:33	10:48	11:03	11:18	11:33	11:48
Moonah	9:21	9:36	9:51	10:06	10:21	10:36	10:51	11:06	11:21	11:36	11:51
New Town	9:24	9:39	9:54	10:09	10:24	10:39	10:54	11:09	11:24	11:39	11:54
Macquarie Point	9:33	9:48	10:03	10:18	10:33	10:48	11:03	11:18	11:33	11:48	12:03
Hobart Elizabeth St	9:35	9:50	10:05	10:20	10:35	10:50	11:05	11:20	11:35	11:50	12:05

	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Glenorchy	12:01	12:16	12:31	12:46	13:01	13:16	13:31	13:46	14:01	14:16	14:31
Derwent Park	12:03	12:18	12:33	12:48	13:03	13:18	13:33	13:48	14:03	14:18	14:33
Moonah	12:06	12:21	12:36	12:51	13:06	13:21	13:36	13:51	14:06	14:21	14:36
New Town	12:09	12:24	12:39	12:54	13:09	13:24	13:39	13:54	14:09	14:24	14:39
Macquarie Point	12:18	12:33	12:48	13:03	13:18	13:33	13:48	14:03	14:18	14:33	14:48
Hobart Elizabeth St	12:20	12:35	12:50	13:05	13:20	13:35	13:50	14:05	14:20	14:35	14:50

	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Glenorchy	14:46	15:01	15:16	15:31	15:46	16:01	16:16	16:31	16:46	17:01	17:16
Derwent Park	14:48	15:03	15:18	15:33	15:48	16:03	16:18	16:33	16:48	17:03	17:18
Moonah	14:51	15:06	15:21	15:36	15:51	16:06	16:21	16:36	16:51	17:06	17:21
New Town	14:54	15:09	15:24	15:39	15:54	16:09	16:24	16:39	16:54	17:09	17:24
Macquarie Point	15:03	15:18	15:33	15:48	16:03	16:18	16:33	16:48	17:03	17:18	17:33
Hobart Elizabeth St	15:05	15:20	15:35	15:50	16:05	16:20	16:35	16:50	17:05	17:20	17:35

	pm	pm	pm	pm	pm
Glenorchy	17:31	17:46	18:01	18:31	19:01
Derwent Park	17:33	17:48	18:03	18:33	19:03
Moonah	17:36	17:51	18:06	18:36	19:06
New Town	17:39	17:54	18:09	18:39	19:09
Macquarie Point	17:48	18:03	18:18	18:47	19:17
Hobart Elizabeth St	17:50	18:05	18:20	18:49	19:19

OUTBOUND: ELIZABETH ST (FRANKLIN SQUARE) > MACQUARIE POINT > NEW TOWN > MOONAH > DERWENT PARK > GLENORCHY

Monday to Friday

	am	am	am	am	am	am	am	am	am	am	am
Hobart Elizabeth St	6:22	6:52	7:22	7:37	7:52	8:07	8:22	8:37	8:52	9:07	9:22
Macquarie Point	6:24	6:54	7:24	7:39	7:54	8:09	8:24	8:39	8:54	9:09	9:24
New Town	6:33	7:03	7:33	7:48	8:03	8:18	8:33	8:48	9:03	9:18	9:33
Moonah	6:36	7:06	7:36	7:51	8:06	8:21	8:36	8:51	9:06	9:21	9:36
Derwent Park	6:39	7:09	7:39	7:54	8:09	8:24	8:39	8:54	9:09	9:24	9:39
Glenorchy	6:41	7:11	7:41	7:56	8:11	8:26	8:41	8:56	9:11	9:26	9:41

	am	am	am	am	am	am	am	am	pm	pm	pm
Hobart Elizabeth St	9:37	9:52	10:07	10:22	10:37	10:52	11:07	11:22	11:37	11:52	12:07
Macquarie Point	9:39	9:54	10:09	10:24	10:39	10:54	11:09	11:24	11:39	11:54	12:09
New Town	9:48	10:03	10:18	10:33	10:48	11:03	11:18	11:33	11:48	12:03	12:18
Moonah	9:51	10:06	10:21	10:36	10:51	11:06	11:21	11:36	11:51	12:06	12:21
Derwent Park	9:54	10:09	10:24	10:39	10:54	11:09	11:24	11:39	11:54	12:09	12:24
Glenorchy	9:56	10:11	10:26	10:41	10:56	11:11	11:26	11:41	11:56	12:11	12:26

	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	12:22	12:37	12:52	13:07	13:22	13:37	13:52	14:07	14:22	14:37	14:52
Macquarie Point	12:24	12:39	12:54	13:09	13:24	13:39	13:54	14:09	14:24	14:39	14:54
New Town	12:33	12:48	13:03	13:18	13:33	13:48	14:03	14:18	14:33	14:48	15:03
Moonah	12:36	12:51	13:06	13:21	13:36	13:51	14:06	14:21	14:36	14:51	15:06
Derwent Park	12:39	12:54	13:09	13:24	13:39	13:54	14:09	14:24	14:39	14:54	15:09
Glenorchy	12:41	12:56	13:11	13:26	13:41	13:56	14:11	14:26	14:41	14:56	15:11

	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	15:07	15:22	15:37	15:52	16:07	16:22	16:37	16:52	17:07	17:22	17:37
Macquarie Point	15:09	15:24	15:39	15:54	16:09	16:24	16:39	16:54	17:09	17:24	17:39
New Town	15:18	15:33	15:48	16:03	16:18	16:33	16:48	17:03	17:18	17:33	17:48
Moonah	15:21	15:36	15:51	16:06	16:21	16:36	16:51	17:06	17:21	17:36	17:51
Derwent Park	15:24	15:39	15:54	16:09	16:24	16:39	16:54	17:09	17:24	17:39	17:54
Glenorchy	15:26	15:41	15:56	16:11	16:26	16:41	16:56	17:11	17:26	17:41	17:56

	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	17:52	18:07	18:22	18:52	19:22	19:52
Macquarie Point	17:54	18:09	18:24	18:54	19:24	19:54
New Town	18:03	18:18	18:33	19:03	19:33	20:01
Moonah	18:06	18:21	18:36	19:06	19:36	20:03
Derwent Park	18:09	18:24	18:39	19:09	19:39	20:05
Glenorchy	18:11	18:26	18:41	19:11	19:41	20:07

Source: DIER

Figure E5 OOSM 4 indicative proposed timetable - weekends

OPTIMAL OPERATING SERVICE MODEL 4 (ILLUSTRATIVE AND INDICATIVE TIMETABLE ONLY)

Six Station High Access Focus

INBOUND: GLENORCHY > DERWENT PARK > MOONAH > NEW TOWN > MACQUARIE POINT > ELIZABETH ST (FRANKLIN SQUARE)

Saturday

	am	am	am	am	am	am	am	am	pm	pm	pm
Glenorchy	8:01	8:31	9:01	9:31	10:01	10:31	11:01	11:31	12:01	12:31	13:01
Derwent Park	8:03	8:34	9:04	9:34	10:04	10:34	11:04	11:34	12:04	12:34	13:04
Moonah	8:05	8:36	9:06	9:36	10:06	10:36	11:06	11:36	12:06	12:36	13:06
New Town	8:07	8:39	9:09	9:39	10:09	10:39	11:09	11:39	12:09	12:39	13:09
Macquarie Point	8:14	8:47	9:17	9:47	10:17	10:47	11:17	11:47	12:17	12:47	13:17
Hobart Elizabeth St	8:16	8:49	9:19	9:49	10:19	10:49	11:19	11:49	12:19	12:49	13:19
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Glenorchy	13:31	14:01	14:31	15:01	15:31	16:01	16:31	17:01	17:31	18:01	18:31
Derwent Park	13:34	14:04	14:34	15:04	15:34	16:04	16:34	17:04	17:34	18:04	18:34
Moonah	13:36	14:06	14:36	15:06	15:36	16:06	16:36	17:06	17:36	18:06	18:36
New Town	13:39	14:09	14:39	15:09	15:39	16:09	16:39	17:09	17:39	18:09	18:39
Macquarie Point	13:47	14:17	14:47	15:17	15:47	16:17	16:47	17:17	17:47	18:17	18:47
Hobart Elizabeth St	13:49	14:19	14:49	15:19	15:49	16:19	16:49	17:19	17:49	18:19	18:49
	pm										
Glenorchy	19:01										
Derwent Park	19:04										
Moonah	19:06										
New Town	19:09										
Macquarie Point	19:17										
Hobart Elizabeth St	19:19										

Sunday and Public Holidays

	am	am	am	am	am	am	pm	pm	pm	pm	pm
Glenorchy	9:01	9:31	10:01	10:31	11:01	11:31	12:01	12:31	13:01	13:31	14:01
Derwent Park	9:03	9:34	10:04	10:34	11:04	11:34	12:04	12:34	13:04	13:34	14:04
Moonah	9:05	9:36	10:06	10:36	11:06	11:36	12:06	12:36	13:06	13:36	14:06
New Town	9:07	9:39	10:09	10:39	11:09	11:39	12:09	12:39	13:09	13:39	14:09
Macquarie Point	9:14	9:47	10:17	10:47	11:17	11:47	12:17	12:47	13:17	13:47	14:17
Hobart Elizabeth St	9:16	9:49	10:19	10:49	11:19	11:49	12:19	12:49	13:19	13:49	14:19
	pm	pm	pm	pm	pm	pm	pm	pm			
Glenorchy	14:31	15:01	15:31	16:01	16:31	17:01	17:31	18:01			
Derwent Park	14:34	15:04	15:34	16:04	16:34	17:04	17:34	18:04			
Moonah	14:36	15:06	15:36	16:06	16:36	17:06	17:36	18:06			
New Town	14:39	15:09	15:39	16:09	16:39	17:09	17:39	18:09			
Macquarie Point	14:47	15:17	15:47	16:17	16:47	17:17	17:47	18:17			
Hobart Elizabeth St	14:49	15:19	15:49	16:19	16:49	17:19	17:49	18:19			

OUTBOUND: ELIZABETH ST (FRANKLIN SQUARE) > MACQUARIE POINT > NEW TOWN > MOONAH > DERWENT PARK > GLENORCHY

Saturday

	am	am	am	am	am	am	pm	pm	pm	pm	pm
Hobart Elizabeth St	8:23	8:53	9:23	9:53	10:23	10:53	11:23	11:53	12:23	12:53	13:23
Macquarie Point	8:25	8:55	9:25	9:55	10:25	10:55	11:25	11:55	12:25	12:55	13:25
New Town	8:33	9:03	9:33	10:03	10:33	11:03	11:33	12:03	12:33	13:03	13:33
Moonah	8:36	9:06	9:36	10:06	10:36	11:06	11:36	12:06	12:36	13:06	13:36
Derwent Park	8:38	9:08	9:38	10:08	10:38	11:08	11:38	12:08	12:38	13:08	13:38
Glenorchy	8:41	9:11	9:41	10:11	10:41	11:11	11:41	12:11	12:41	13:11	13:41
	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm	pm
Hobart Elizabeth St	13:53	14:23	14:53	15:23	15:53	16:23	16:53	17:23	17:53	18:23	18:53
Macquarie Point	13:55	14:25	14:55	15:25	15:55	16:25	16:55	17:25	17:55	18:25	18:55
New Town	14:03	14:33	15:03	15:33	16:03	16:33	17:03	17:33	18:03	18:33	19:03
Moonah	14:06	14:36	15:06	15:36	16:06	16:36	17:06	17:36	18:06	18:36	19:06
Derwent Park	14:08	14:38	15:08	15:38	16:08	16:38	17:08	17:38	18:08	18:38	19:08
Glenorchy	14:11	14:41	15:11	15:41	16:11	16:41	17:11	17:41	18:11	18:41	19:11
	pm										
Hobart Elizabeth St	19:23										
Macquarie Point	19:25										
New Town	19:32										
Moonah	19:34										
Derwent Park	19:36										
Glenorchy	19:38										

Sunday and Public Holidays

	am	am	am	am	am	am	pm	pm	pm	pm	pm
Hobart Elizabeth St	9:23	9:53	10:23	10:53	11:23	11:53	12:23	12:53	13:23	13:53	14:23
Macquarie Point	9:25	9:55	10:25	10:55	11:25	11:55	12:25	12:55	13:25	13:55	14:25
New Town	9:33	10:03	10:33	11:03	11:33	12:03	12:33	13:03	13:33	14:03	14:33
Moonah	9:36	10:06	10:36	11:06	11:36	12:06	12:36	13:06	13:36	14:06	14:36
Derwent Park	9:38	10:08	10:38	11:08	11:38	12:08	12:38	13:08	13:38	14:08	14:38
Glenorchy	9:41	10:11	10:41	11:11	11:41	12:11	12:41	13:11	13:41	14:11	14:41
	pm	pm	pm	pm	pm	pm	pm	pm			
Hobart Elizabeth St	14:53	15:23	15:53	16:23	16:53	17:23	17:53	18:23			
Macquarie Point	14:55	15:25	15:55	16:25	16:55	17:25	17:55	18:25			
New Town	15:03	15:33	16:03	16:33	17:03	17:33	18:03	18:32			
Moonah	15:06	15:36	16:06	16:36	17:06	17:36	18:06	18:34			
Derwent Park	15:08	15:38	16:08	16:38	17:08	17:38	18:08	18:36			
Glenorchy	15:11	15:41	16:11	16:41	17:11	17:41	18:11	18:38			

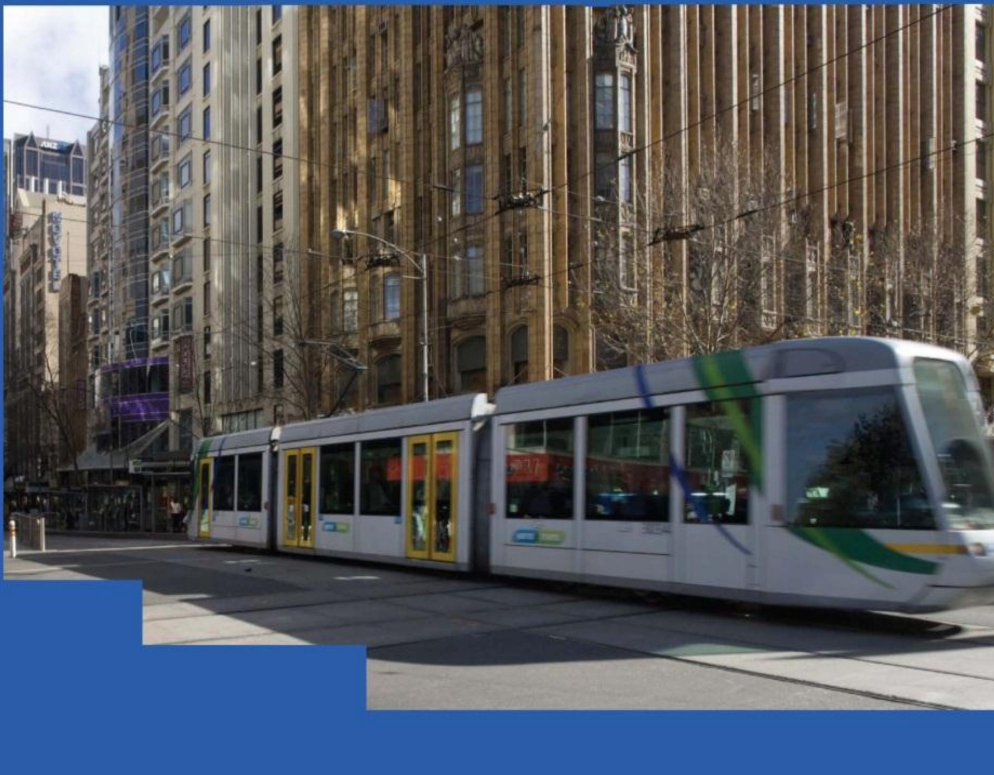
Source: DIER

Appendix F Hyder report

STAGE 1 LIGHT RAIL BUSINESS CASE

HOBART TO GLENORCHY

Optimal Operating Service Models



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Department of Infrastructure, Energy and Resources

Stage 1 Light Rail Business Case

Hobart to Glenorchy

Optimal Operating Service Models

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Report No F0002-AA003945-AA02

Date 06 May 2013

This report has been prepared for ACIL Tasman on behalf of the Department of Infrastructure, Energy and Resources in accordance with the terms and conditions of appointment Hobart Light Rail Business Case dated 23rd January 2013. Hyder Consulting Pty Ltd (ABN 76 104 485 289) cannot accept any responsibility for any use of or reliance on the contents of this report by any third party.

Revisions

00	09/04/2013	Issued for comments	Department of Infrastructure, Energy and Resources	Peter Kruup
01	06/05/2013	Final Report	Department of Infrastructure, Energy and Resources	Peter Kruup

Disclaimer

In preparing this report, Hyder has relied upon the models, information and data provided by, and assumptions made by, many different entities. While Hyder has reviewed the sources of information, models, data and assumptions, Hyder disclaims and will not assume responsibility for the accuracy of such data, models, information and assumptions received from any such entity.

Any forecast is an opinion based on reasonable investigation as to a future event and is inherently subject to uncertainties. Inevitably, some assumptions used to develop the forecasts will not be realised and unanticipated events and circumstances may occur. Therefore Hyder cannot provide any form of assurance that the forecasts documented in this report will be achieved. Actual outcomes will vary from that forecast and the variations may be significant.

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CONTENTS

APPENDICES

1 INTRODUCTION

Hyder Consulting Pty Limited (Hyder) formed part of a team that delivered the Light Rail Business Case for Hobart on behalf of the Department of Infrastructure, Energy and Resources (DIER).

As part of Hyder's involvement during Hobart Light Business Case delivered in June 2011, Optimal Operating Services Models (OOSMs) for introduction of a light rail system in Hobart were developed for the agreed corridor study area between Claremont and Hobart. As part of the OOSM development process various elements were considered resulting in two optimal options being developed. The elements considered included:

- Corridor alignment
- Existing track condition and configuration
- Rolling stock options and use of electrification
- Signalling options
- Maintenance and stabling facilities.

The final report Hobart Light Rail Business Case – Optimal Operating Service Models, Report Number F0001-AA003945-AA01 was submitted to DIER on 8 June 2011 detailing the findings on Optimal Operating Service Models for the area between Claremont and Hobart.

Stage 1 Light Rail Business Case (Hobart to Glenorchy)

To support the business case submission in 2013, Hyder has been engaged by ACIL Tasman on behalf of DIER to complete a review of the proposed Hobart Light Rail (HLR) alignment, following the optimisation of the initial OOSM to run between Hobart and Glenorchy.

This report represents a continuation of the work undertaken during the original project in 2011 and specifically covers Optimal Operating Service Models for a study area between Glenorchy and Hobart. Most of the study parameters and assumptions of the study undertaken in 2011 are the same and they have not been repeated in this report therefore this report should be read in conjunction with the 2011 report F0001-AA003945-AA01. The report can be found at: http://www.transport.tas.gov.au/miscellaneous/northern_suburbs_to_hobart_cbd_light_rail_business_case/what_is_stage_2

The scope of this study includes consideration of four Optimal Operating Services Models (OOSM). The four OOSM options developed feature varied stopping patterns to suite potential demand along the HLR corridor. As part of a review the study parameters Hyder has completed:

- High level revision of the terminus location in Hobart CBD and identification of the Glenorchy terminus location
- High level identification of intermediate stop locations and to which OOSM they apply
- Study of the potential line speed for the alignment
- Overview of track construction requirements
- Review of track gauge options
- Review of rolling stock options
- Update cost estimates to reflect changes to the OOSM's.

These key elements are outlined through the report, with detailed cost estimates and rail modelling provided in the appendices.

2 OOSM ASSESSMENT OPTIONS

The proposed Hobart Light Rail (HLR) will run between Hobart CBD (Elizabeth Street) and Glenorchy, in the vicinity of Peltro Street. As a result of the shorter alignment, Hyder has completed a review of the original assumptions and cost estimates and revising the data where required. The new OOSM's developed are outlined in this report, along with complete with revised cost estimates and rail modelling.

2.1 STUDY PARAMETERS

The parameters remain consistent with those developed as part of the original business case submission in 2011. These were discussed and agreed with DIER during the consultation process held on 14 and 15 April 2011. Some alterations have been made to suit the new terminus location at Glenorchy:

- The OOSMs are only considered for the section between Glenorchy and Hobart
- All OOSM options are now for electrified Light Rail Vehicles (LRV's) only
- The service models need to achieve a 15 minute interval rail service
- There are up to four intermediate stops and two terminus points on the route. These are: Hobart CBD; Macquarie Point, New Town; Moonah; Derwent Park and Glenorchy. The infrastructure required at the stops must satisfy the minimum safety and DDA requirements
- The upgraded track could be installed to standard gauge, but must retain provision for narrow gauge

2.2 OOSM OVERVIEW

The scope of this study includes consideration of four Optimal Operating Services Models (OOSM) as follows:

- OOSM 1 – Three stop fast system
- OOSM 2 – Four stop northern focus
- OOSM 3 – Five stop suburban focus
- OOSM 4 – Six stop high access focus

The initial target for all of the OOSM options is to establish a 15 minute frequency and determine the fastest end-to-end journey times using as few Light Rail Vehicles (LRV) as possible with minimal infrastructure expenditure.

To complete the OOSM revisions, a specialist rail modelling consultant, Plateway, was engaged to consider the service model options and develop tentative timetables by analysing the track alignment including curves, grades, travel speed, travel time, number of passing loops, number of stops and terminus points.

A summary of the rail modelling is outlined in Section 6 of this report and a copy of the rail modelling report is attached in Appendix A. **Table 2-1** summarises the main variables for the OOSM options.

OOSM VARIABLE	OOSM OPTION			
	01	02	03	04
Terminus – Elizabeth Street	✓	✓	✓	✓
Stop – Macquarie Point				✓
Stop – New Town			✓	✓
Stop – Moonah	✓	✓	✓	✓
Stop – Derwent Park		✓	✓	✓
Terminus – Glenorchy	✓	✓	✓	✓
Journey Time	16.5 min	17 min	18min	19min
Service Frequency – Peak	15 min			
Service Frequency – Off Peak	30 min			
Core Bus Feeder Frequency – Peak	15 min			
Core Bus Feeder Frequency – Off Peak	30 min			
Peak Service Hours (LRT & Bus)	07:00 – 18:30			
Off Peak Service Hours (LRT & Bus)	06:00 – 07:00 and 18:30 – 19:30			
Saturday Service Hours (Off Peak)	08:00 – 19:00			
Sunday Service Hours (Off Peak)	09:00 – 18:00			

Table 2-1: *Core Optimal Operating Services Models*

3 REVIEW OF HOBART TERMINUS LOCATION

In the 2011 HLR Business Case OOSM report, the terminal location was proposed for Mawson Place, with an option for a short extension to the southern end of Elizabeth Street. These locations would necessitate passengers crossing Davey and Macquarie Streets using existing infrastructure to reach the CBD.

Figure 3-1: *Mawson Place Terminal – from the 2011 Business Case OOSM*

Figure 3-2: *Elizabeth Street Terminal – from the 2011 Business Case OOSM*

Following consultation, the site of the terminus was reviewed in order to find a suitable location closer to the existing Hobart City Interchange, assumed to be the ‘centre of activity’ at the intersection of Elizabeth Street and Macquarie Street. Any such option strengthens connectivity to the CBD and existing transport hub, but also increases the LRV’s interaction with existing traffic.

Three terminus sites/route options were considered on Collins, two on Macquarie Street and three on Elizabeth Street. Various alignment options were then reviewed between the terminus site and existing Hobart rail yard. A number of options were assessed, as shown in **Figure 3-3**.

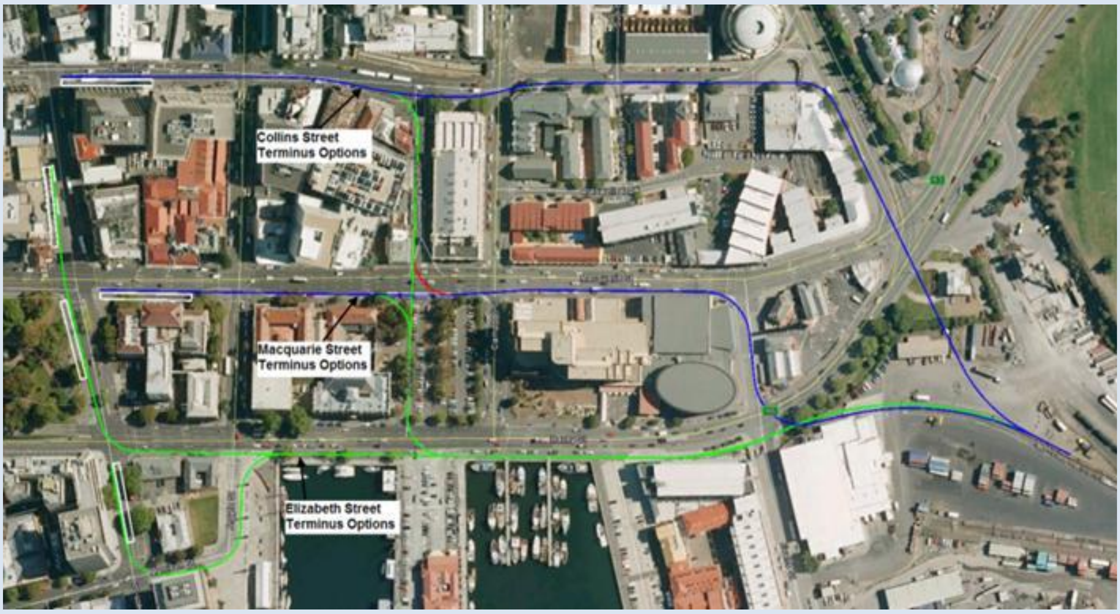

Figure 3-3: *HLR Terminus and alignment options Map Data: Sensis Pty Ltd, Google 2013*

A preferred alignment was then chosen using the measurable parameters detailed in **Table 3-2** and evaluated against the criteria shown in **Table 3-3**. A Terminus on Elizabeth Street at Franklin Square has been selected as a preferred option as detailed in Section 3.4. The criteria detailed in **Table 3-3** are designed to consider, at a high level, the construction cost, operational and accessibility impacts of the various terminus site options. The terminus presenting the most suitable overall results was then carried forward to the updated OOSM scenarios.

Table 3-2 details the measurable parameters used in **Table 3-3** to complete the alignment assessment.

MEASURABLE	REASONING AND PREFERRED OUTCOME
Distance from Hobart Rail Yard (m)	Affects construction cost and journey time. Lower figure preferred.
Pedestrian distance from terminus point to Elizabeth St / Macquarie St intersection (m)	Influences passenger decision into the convenience of the HLR. Lower figure is preferred, although variations around gradients and number of traffic intersections should be considered.
Number of low-speed 25m radius curves	Affects construction cost and journey time. Increases long-term maintenance. Lower figure preferred.
Platform design compliance	Influences passenger opinion of accessibility. Non-compliant locations are not preferred, unless justification can be provided.
Provision for future 2nd platform for the terminus points	Affects the future expansion and operational flexibility of HLR system. Provision for a 2nd platform is preferred, but it may be possible to provide an alternative solution.
Number of road intersections affected	Affects construction cost and journey time. Also impacts existing traffic flows. Lower figure preferred.
Length of existing traffic lanes removed (m)	Impacts existing traffic flows. As a single bi-directional track is proposed, the LRV's cannot share with existing traffic. Segregated lanes increase the overall scope of project to require large-scale road works if a significant amount of road lane acquisition is required. Lower figure preferred.

Table 3-2: *Hobart CBD alignment comparison – Measurable parameters*

		COLLINS STREET OPTIONS			MACQUARIE ST OPTIONS		ELIZABETH STREET OPTIONS		
MEASURABLE	**MAWSON PLACE**	**OPT 01**	**OPT 02**	**OPT 03**	**OPT 01**	**OPT 02**	**OPT 01**	**OPT 02**	**OPT 03**
Distance from Hobart Rail Yard (m)	530	790	885	835	700	730	730	730	810
Pedestrian distance from Terminus to Elizabeth St / Macquarie St intersection (m)	210	115	115	115	0	0	0	110	50
Number of low-speed 25m radius curves	0	2	2	4	2	2	1	3	1
Platform design compliance	✓	✓	✓	✓	✓	✓	×	✓	✓
Provision for future 2nd platform	×	×	×	×	×	×	✓	✓	×
Number of intersections affected	1	5	4	5	4	3	3	2	4
Length of existing traffic lanes removed (m)	0	540	310	565	470	180	75	60	135

Table 3-3: *Comparison of Hobart CBD alignments*

3.1 COLLINS STREET OPTIONS

A terminus in Collins Street provides good access to the CBD, existing transport hub and is closer to Royal Hobart Hospital. However, all 3 possible options require longer sections of street-running and considerable modifications to existing traffic lanes, priorities and intersection interfaces. This would influence timetable management and overall CAPEX cost.

The proposed terminus site from the Collins Street terminus options is at the intersection of Collins and Elizabeth Street. The existing pedestrian walkway could be extended into the road to create the LRV platform. Due to the existing narrow road width, it will be difficult to provide sufficient space for a second platform. This would restrict future operational flexibility.

Figure 3-4: *Collins Street Terminus Options Map Data: Sensis Pty Ltd, Google 2013*

3.1.1 OPTION 1 VIA BROOKER AVENUE

This option would begin with a westerly departure from the rail yards, crossing the driveway of the Royal Engineers Building. It would require a complex crossing of the intersection between Tasman Highway, Davey and Macquarie Streets and Brooker Avenue. This could place considerable pressure on the existing intersection which is the convergence of the main roads running through Hobart on the North-South axis.

The alignment runs briefly along Brooker Avenue, requiring a traffic lane to be acquired. It would then turn left from into Collins Street, running to the terminus at Elizabeth Street. The alignment of Collins Street is not ideal with some moderate curves between Campbell and Elizabeth Street. The road width varies between 8-12m, from which a minimum of 4m reserve would need to be found for the HLR. This would require a major revision to existing traffic operations to accommodate the reduced road width.

One possible option would be for the LRV's to running in a central position with a traffic lane on either side. This would need to be clearly marked, with reduced traffic and LRV speeds due to the restrictive width.

3.1.2 OPTION 2 VIA MACQUARIE STREET / MARKET PLACE

Option 2 follows the alignment proposed in the initial business case proposal (2011), along the disused harbour rail alignment, before turning right across Davey Street into Dunn Place, prior to the original Mawson Place terminus.

Dunn Place is an existing car park access road which could be used with minimal impact to existing parking, however some existing trees would need to be removed.

The alignment then crosses Macquarie Street before traveling along Market Place, requiring an existing traffic lane to be acquired. Following a left turn into Collins Street, the alignment then follows option 1 to the proposed terminus, as detailed in Section 3.1.1.

3.1.3 OPTION 3 VIA DAVEY STREET / MARKET PLACE

The alignment maximises the use of Hobart Rail Yards but then makes an immediate turn into Evans Street before shortly turning again into Macquarie Street. The short section along the centre of Evans Street is complex due to the small radius curves at either end. This would likely require the acquisition of two traffic lanes to safely accommodate the LRV envelope.

The alignment would then run along the eastern side of Macquarie Street, crossing Campbell Street intersection. This would require the acquisition of one of the five existing traffic lanes.

A right turn across Macquarie Street onto Market Place joins the alignment to Option 2, as detailed in Section 3.1.2.

3.2 MACQUARIE STREET OPTIONS

The Macquarie Street terminus option provides a platform in close proximity to the CBD and existing transport hub, at the front of Hobart Town Hall.

This site would require longer sections of street running, plus removal of existing traffic lanes and parking. Alterations to traffic and intersection priorities would also be necessary. This would influence timetable management and overall CAPEX cost. There may also be a risk of negative feedback regarding the potential placement of a platform shelters and overhead wiring in front of the town hall.

The proposed platform can be formed by raising the existing footpath kerbs to platform height. Due to the location, it is not possible to provide two platform faces without unacceptable impacts to traffic flow on Macquarie Street. If additional capacity is required, it should be possible in the future to construction both option 1 and 2 as detailed below to provide a long passing loop.

Figure 3-5: *Macquarie Street Terminus Options Map Data: Sensis Pty Ltd, Google 2013*

3.2.1 OPTION 1 VIA MACQUARIE STREET / EVANS STREET

This option follows the Collins Street Option 2 alignment discussed in Section 3.1.2, and then continues along the eastern side of Macquarie Street to the Elizabeth Street intersection.

As previously discussed, the alignment would require a central position in Evans Street, acquiring two lanes, and the eastern position along Macquarie Street requires the acquisition of one lane and /or parking spaces.

3.2.2 OPTION 2 VIA DAVEY STREET / DUNN PLACE

This option follows the Collins Street Option 3 alignment discussed in Section 3.1.3, before turning left onto Macquarie Street and proceeding to the terminus at the Elizabeth Street intersection.

This option leads to the loss of some parking and a traffic lane on Macquarie Street, as well as modifications to Dunn Place, including the removal of some trees.

3.3 ELIZABETH STREET OPTIONS

There are three terminus options within Elizabeth Street. All alignment options are common as far as the original Mawson Place terminus, at the intersection with Argyle Street. From this point, three options are considered and detailed below.

The common alignment section follows the disused harbour rail alignment from Hobart rail yards to the Argyle Street intersection. Minimal segregation works will be required from existing traffic on Davey Street, although appropriate signage should be provided along the shared pedestrian / LRV waterfront section.

Figure 3-6: *Elizabeth Street Terminus Options Map Data: Sensis Pty Ltd, Google 2013*

3.3.1 OPTION 1 FRANKLIN SQUARE TERMINUS

This option continues the original alignment (2011) from Mawson Place across Argyle Street, before turning right into Elizabeth Street and terminating adjacent to Franklin Square.

Figure 3-7: *Franklin Square Terminus Map Data: Sensis Pty Ltd, Google 2013*

The proposed platform can be formed by raising the existing footpath kerbs to platform height. Existing gradients would result in the platform being on a slope of approximately 1 in 20. This may require the provision of additional landings to assist wheelchair users.

Modifications to traffic priority and access would be required on and between Davey Street, Argyle Street and Elizabeth Street.

The existing left turn lane from Davey Street into Elizabeth Street would need to be acquired for use by LRV's only. To minimise impact on traffic flows along the A6 trunk route, it is expected that left turn traffic would need to continue to the existing turn lane at the Murray Street intersection.

Bus stop 'M' (South Hobart) would need to be relocated. If a second platform is required in the future, a wider footprint can be accommodated, with some traffic removed or restricted to public transport only between Davey and Macquarie Street.

To satisfy LRV timetable requirements, traffic light priority would need to be reconfigured on the intersections between Davey Street and Argyle & Elizabeth Streets.

3.3.2 OPTION 2 VIA DAVEY STREET, ARGYLE AND MORRISON STREET

This extension option from Mawson Place was originally proposed in the document 'Hobart Light Rail Business Case, Optimal Operating Service Modules' (2011). It was intended to locate the terminus closer to the CBD, within sight distance of the bus terminal, for minimal additional capital cost.

The alignment will turn left immediately after passing the Mawson Place terminus, then right onto Morrison Street. This short section will follow the old port railway alignment and will be a slow section due to the small radius curves. From Morrison Street, the alignment turns right immediately into the terminus platform on Elizabeth Street.

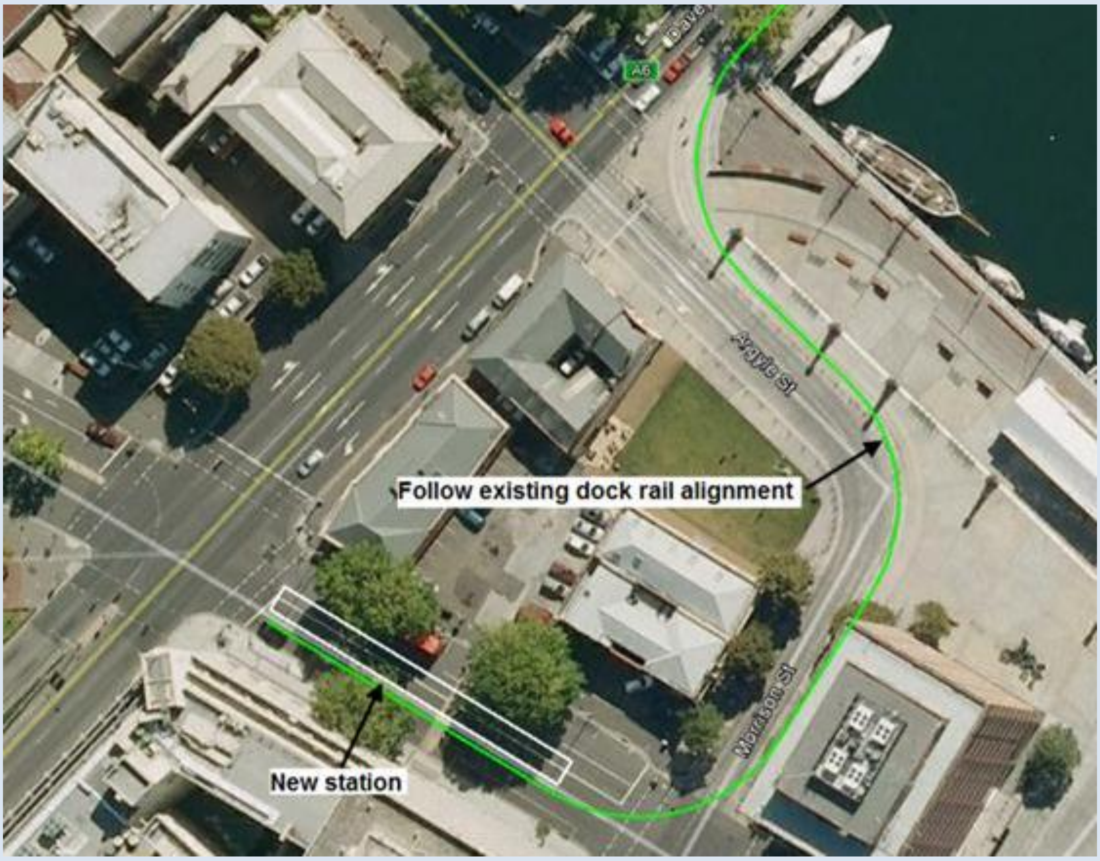

Figure 3-8: *Elizabeth / Davey Street Terminus Map Data: Sensis Pty Ltd, Google 2013*

The proposed platform would occupy a central position in Elizabeth Street, removing two traffic lanes. It should still be possible to incorporate one traffic lane in each direction either side of the LRV tracks. There may need to be a restriction on vehicle access due to potential limited clearances for traffic turning into Elizabeth Street.

Provision for a second platform face is possible, but the maximum length of any platform is approximately 50 metres. This is less than the preferred 60 metres but will provide ample length for standard LRV lengths, which are usually up to 30-35 metres

3.3.3 OPTION 3 VIA DAVEY STREET – BUS MALL

This option is an extension to option 1, detailed in Section 3.3.1. Rather than terminating at Franklin Square, the alignment will extend across Macquarie Street and terminate in the existing Hobart Bus Mall. This option would provide immediate connectivity to the Bus Mall and eliminate the need for passengers to cross either Davey or Macquarie Streets to reach the CBD.

Figure 3-9: *Elizabeth / Macquarie Street Terminus Map Data: Sensis Pty Ltd, Google 2013*

Existing bus services that use stops M, D, C and possibly B would need to be relocated to new stops, either on Macquarie or Collins Street. This may require considerable alterations to existing bus timetables. In addition, traffic priorities would need to be altered along Elizabeth Street, between Davey and Macquarie Streets. These intersections will also require modification, including LRV priority, to ensure operational efficiency.

The terminus can be formed by raising the existing footpath height to form the platform edge. There would be no provision for a second platform face, without relocating the Bus Mall. If additional capacity is required in the future, it should be possible to construct a passing loop on Elizabeth Street, or along Macquarie and Argyle Streets around the Hobart Town Hall.

3.4 PREFERRED TERMINUS LOCATION

Based on the information shown in Section 3, the preferred terminus location is Elizabeth Street Option (Franklin Square), described in Section 3.3.1. This site has been selected due to:

- Proximity to CBD and Bus Mall
- Minimal impact on existing traffic, during construction and operation
- Smallest amount of traffic lane acquisition
- One of the shortest alignments from Hobart Rail Yards and only 200m extension from Mawson Place
- Minimal number of small radius curves, reducing travel time
- Platform is design compliant, some additional DDA features (wheelchair landings on graded sections) may be required

4 OTHER PROPOSED OOSM STOP LOCATIONS

The locations of Glenorchy terminus along with the intermediate stops have been selected to maximise integration with the existing infrastructure and public transport network. As a minimum, the stops are design to accommodate a 60 metre single face platform, with basic shelters, lighting and passenger displays. Access will be via a DDA compliant ramp and a pedestrian crossing where required.

A high-level analysis has been completed on all proposed stop sites to ensure that constructability is achievable whilst meeting the economic requirements for each precinct. Refinements to the stop locations and layouts may be undertaken during the detail design phase and therefore the proposed locations should be considered as indicative.

TERMINUS / STOP	APPLICABLE OOSM OPTION			
	01	02	03	04
Stop – Macquarie Point				✓
Stop – New Town			✓	✓
Stop – Moonah	✓	✓	✓	✓
Stop – Derwent Park		✓	✓	✓
Terminus – Glenorchy	✓	✓	✓	✓

Table 4-4: *Terminus / Stop locations used for each OOSM*

4.1 GLENORCHY

The northern terminus is proposed to be located adjacent to King George V Avenue and Peltro Street. There is an existing pedestrian crossing which could be used to access the terminus. Future provision of a loop or double-track terminus would require modification to the existing disused platform face and track layout to the rail sheds.

Figure 4-10: *Glenorchy Terminus Map Data: Sensis Pty Ltd, Google 2013*

4.2 DERWENT PARK

The proposed location is adjacent to the existing level crossing at Derwent Park Road. The platform can occupy the eastern side of the rail reserve adjoining the warehouse car park. Future provision for a passing loop and second platform face would require modification to the existing bike path and the 'Industrial Heritage Park' currently located on the western side of the rail reserve.

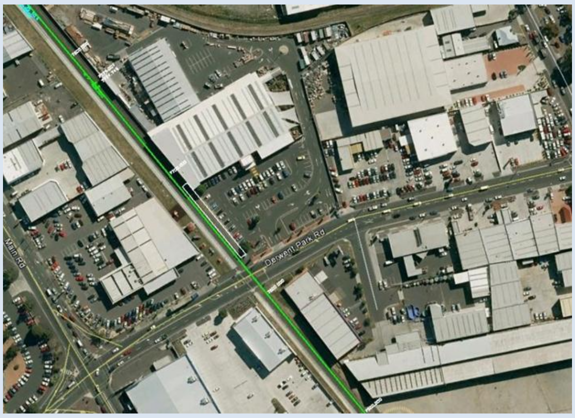

Figure 4-11: *Derwent Park Stop Map Data: Sensis Pty Ltd, Google 2013*

4.3 MOONAH

The proposed location is adjacent to the existing level crossing, on Albert Road between Gatehouse and Station Streets. Provision has been made for a passing loop which is required as the minimum in all OOSM scenarios. To accommodate the loop, an island platform has been proposed to minimise any delays associated with passing LRV's and to reduce construction costs.

Figure 4-12: *Moonah Stop Map Data: Sensis Pty Ltd, Google 2013*

4.4 NEW TOWN

The proposed location is adjacent to Bell Street, close to the existing level crossing on Bay Road. The proposed stop site is set back from Bay Road by approximately 60 metres to avoid siting the platform on a curved alignment. There is an existing platform at this location which would need to be removed, although an upgrade may be a suitable option.

Figure 4-13: *New Town Stop Map Data: Sensis Pty Ltd, Google 2013*

4.5 MACQUARIE POINT

The proposed location of a stop serving the future development at Macquarie point is indicative only and will be subject to review to suit the site development. It is recommended that a reservation suitable for an island platform and a passing loop is provided through the area.

A future loop at Macquarie Point (with or without a stop) may be essential in providing suitable capacity and flexibility, depending on future timetable requirements.

Figure 4-14: *Macquarie Point Stop*

5 ENGINEERING OVERVIEW

In order to meet timetable requirements, it is important that the optimal and maximum operating speed is considered. There are a number of contributing factors reviewed in this section of the report:

- Track geometry
- Track construction standards
- Track gauge
- Rolling stock suitability.

5.1 PROPOSED LINE SPEED

To suit the nature of HLR, adoption of two line speed categories should be considered:

- Urban Environment – Hobart street section
- Light Rail Environment – from rail yards to Glenorchy, within the existing rail corridor.

For the urban environment section, the current line speed parameters used on the Melbourne light rail network by Yarra Trams have been applied. These take in to account the complexities of running around small radius curves (25m) and operation within a pedestrian-focussed environment.

Along the existing rail corridor, best design practices have been adopted. This ensures a suitable ride quality and journey time. As all track will now be reconstructed to a higher specification, greater operating speeds are possible as a result of improved track geometry.

It is also possible to enhance the line speed on a number of curves, by increasing the maximum permissible applied cant and applied deficiency. Limits for both have been chosen that are within the typical maximum for rail operations as it is not expected that the LRV's will travel faster than 80km/h. This will ensure that passenger comfort and ride quality are not sacrificed.

Table 5-5 outlines the proposed line speeds that will be encountered at locations along the HLR alignment.

COMMON CURVE RADIUS	MAXIMUM SPEED
Straight Track (Urban)	30km/h
30m (Urban minimum)	15km/h
Straight Track (Light Rail)	80km/h
100m	40km/h
150m	50km/h
200m	55km/h
250m	65km/h
300m	70km/h
400m or greater	80km/h

Table 5-5: *Line Speed Calculations and Assumptions*

At this stage, the proposed OOSM options are based on a timetabled maximum speed of 60km/h. This allows a competitive journey time and also avoids rapid acceleration / braking which may be necessary between speed-restricted curves if LRV's are timetabled to operate at 80km/h.

However, provision for 80km/h speed limit for the line would allow services to recover lost time due to unexpected delays, which could occur at stops, level crossings, crossing loops or signal controlled intersections. There is potentially up to 90 seconds of recoverable time when considering the whole route, if a maximum speed of 80km/h is adopted.

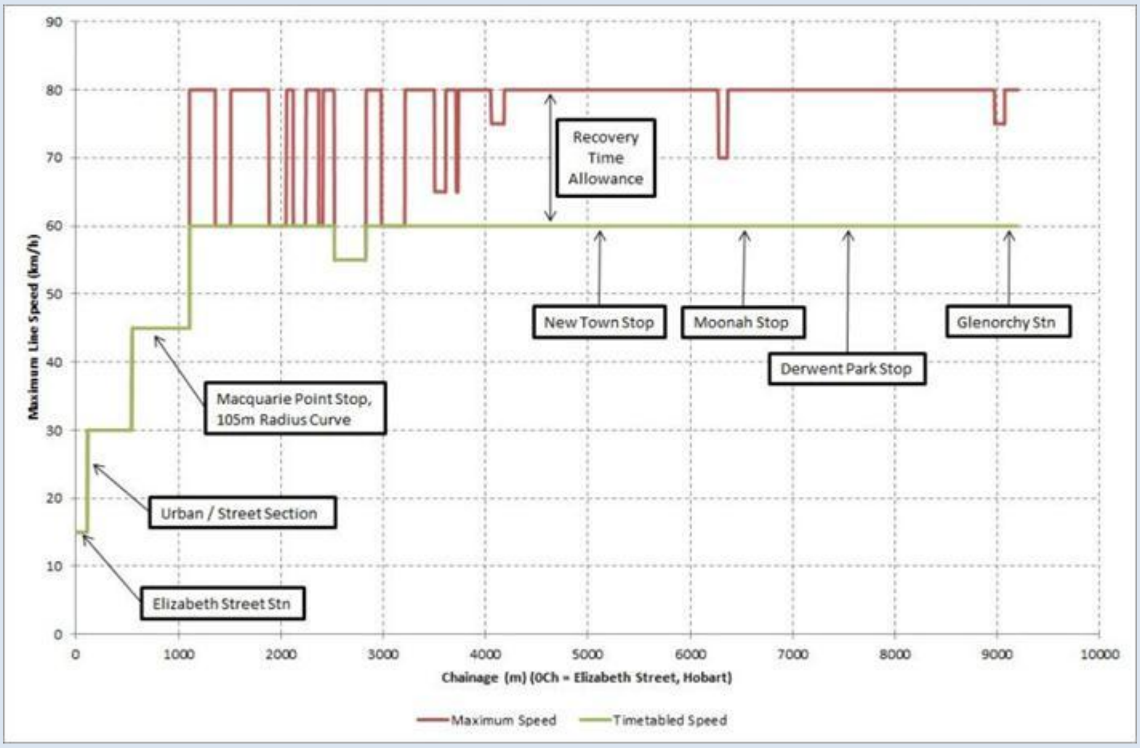

Figure 5-15: *Proposed Route Line Speed*

The majority of the alignment is suitable for 80km/h as shown in **Figure 5-15**, with the exception of:

- 0km – 1km, where the alignment passes through the urban section, Hobart rail yards and a 105m radius curve near Macquarie Point
- 1km – 4km, where the alignment runs along a restrictive corridor between the Domain Highway and the Derwent River.
- 4km – 9km suitable for 80km/h, although LRV's will need to accelerate/decelerate from stops and passing loops.

5.2 TRACK CONSTRUCTION

To suit the line speed required to achieve timetable consistency, it is recommended that full track replacement is budgeted for between Hobart Rail Yards and Glenorchy. This will ensure a suitable ride quality for LRV's travelling at speeds up to 80km/h, with minimal track maintenance required from the start of operations.

A full track construction methodology will be developed during the detail design phase, however as a minimum, the following steps should be considered:

- Remove and dispose of existing rail and sleepers
- Grade formation and prepare subgrade to required minimum CBR, complete formation treatment of any unsuitable areas
- Lay new ballast
- Install Sleepers and rail

- Top up ballast and tamp track to final alignment
- Complete all other works – level crossings, signalling systems, etc.

5.3 TRACK GAUGE

The option to use standard gauge rolling stock has been considered as part of the current OOSM development. Standard gauge is more common on light rail networks than narrow gauge, which represents a realistic opportunity to procure second hand rolling stock, or utilise an 'off the shelf' product, rather than a custom designed LRV to suit narrow gauge.

There are a number of 1000mm gauge networks in Europe which are increasingly enhancing their maximum line speed to suit modern day operations. As a result, there is an increasing amount of modern narrow gauge LRV's available, although they will still require gauge modification – refer to section 8 for details.

For this reason, the option to install standard gauge track has been reviewed and costed. Table 7-4 compares the key feature differentials between the two track gauges.

MEASURABLE	NARROW GAUGE TRACK	STANDARD GAUGE TRACK
Clearing & Grubbing	Clearing & grubbing of formation limits, minimum 5.4m	Additional width required for clearing, approx. 500mm extra width
Formation Works	Subgrade improvements, capping layer installation over 4.4m width	Additional width required, approx. 500mm
Ballast	Current estimate of approximately 2.8t ballast per metre	Additional ballast, approximately 3.18t per metre
Sleepers	Typical narrow gauge design, steel or concrete.	Typical standard gauge design, steel or concrete. Similar cost per unit
Rail	Same rail for both options.	
Operating Speeds	Narrow gauge reduces ride quality.	Wider gauge improves ride quality, allows for greater comfort and speed in curved sections. Numerous standard gauge LRV networks operating at up to 80-100km/h
Ongoing Maintenance	Track compatible with existing narrow gauge network, allowing for transfer of skills from TasRail maintainers, and compatibility of existing rail plant.	Existing rail plant will not be compatible. This may result in future maintenance costs increasing due to the certain plant items being supplied from mainland Australia, or a more expensive alternative developed.

MEASURABLE	NARROW GAUGE TRACK	STANDARD GAUGE TRACK
Heritage and Freight Services	Option to operate between Glenorchy and Hobart Rail Yard	To operate between Glenorchy and Hobart Rail Yard: Modify heritage and freight vehicles, losing compatibility with the rest of the network Provide option for future dual gauge track, at an additional cost in the future
LRV cost	Approximately 10% premium for a new LRV	Opportunity to procure second hand LRV, for further cost reduction from new unit
Overall Cost Difference	Saving for using standard gauge may be as little as 1% of total CAPEX cost, providing little or no benefit. This includes making provision for dual gauge, but not installing the additional components. There may be further savings during rolling stock procurement.	

Table 5-6: *Narrow and Standard Gauge Comparison*

In terms of construction, standard gauge track will cost marginally more than narrow gauge due to the formation being wider. This cost should be offset by the saving in rolling stock procurement. The cost of the rolling stock is variable and will be dependent on gauge chosen as well as availability at the time of order.

5.4 PROVISION FOR DUAL GAUGE

If a standard gauge light rail system is preferred, the use of dual gauge sleepers should be considered to accommodate any future requirement to operate freight or heritage services between Glenorchy and Hobart.

Dual gauge sleepers have no additional CAPEX cost, assuming a single gauge setup is adopted at the start of the project. At a future date, additional components can be fitted to carry the 3rd rail required to accommodate narrow gauge services.

5.5 ROLLING STOCK

Unlike many traditional light rail systems, HLR will run mostly within an established rail corridor. LRVs suited to these conditions should be procured to ensure that full advantage can be taken of higher-speed operation when not on the street sections of the route. Bogies suited for speeds up to 100km/h are frequently fitted to LRV's, to suit modern systems which often feature considerable lengths of long-distance running with small sections of street running at either end of a route. The Adelaide tram network provides a good example of this, as do the St Kilda and Port Melbourne tram routes in Melbourne.

Some manufacturers produce LRVs designed to run on 1000mm gauge, which should be relatively straightforward to modify to 1067mm gauge, however a high premium could still be expected to complete this work. **Figure 5-16** shows a modern LRV in Bilbao, Spain. This system operates on 1000mm gauge, due in part to restrictive clearances to existing buildings. These vehicles are designed with a maximum speed of 50km/h. Note the large overhang of the 2.6m vehicle in the image.

Figure 5-16: *CAF EuskoTran, Bilbao – Author 'Ardfern', 15 July 2010*

Figure 5-17: *CAF tram, Belgrade- Author 'Aleksandar', 28 August 2011*

The CAF manufactured LRV shown in **Figure 5-17** is currently in use in Belgrade where significant portions of the light rail network operates in dedicated rail corridors. It is a 1000mm gauge LRV, with a maximum service speed of 80km/h. The vehicle is built to a smaller width (2.3m) which assists with stability at speed but will have a small reduction of total capacity.

The opportunity to procure rolling stock 'off the shelf' or second hand led to a review of the option to provide standard gauge track. LRV's are more readily available with standard gauge bogies and opens up opportunities to utilise existing rolling stock from other cities. It would cost less to construct a standard gauge LRV compared to developing a narrow gauge version with bespoke bogies.

For the purpose of this OOSM assessment, an electrified LRV using Overhead Wire (OHW) has been adopted. It is also assumed that the LRVs will run on bogies suitable for higher speeds, which are readily available. This will ensure a comfortable ride quality along the rail corridor is achieved.

In order to accommodate for higher demand during the peak periods and provide capacity for increased demand in the future a 40m long LRVs were selected for this study.

6 SUMMARY OF OOSM ANALYSIS

The Core Optimal Operating Services Models (OOSM) has been developed to incorporate a standard service frequency, with variances in stopping patterns and route development.

- OOSM 1 – Three stop fast system
- OOSM 2 – Four stop northern focus
- OOSM 3 – Five stop suburban focus
- OOSM 4 – Six stop high access focus.

Table 6-7 summarises the key variables for each OOSM option.

OOSM VARIABLE	OOSM OPTION			
	01	02	03	04
Terminus – Elizabeth Street	✓	✓	✓	✓
Stop – Macquarie Point				✓
Stop – New Town			✓	✓
Stop – Moonah	✓	✓	✓	✓
Stop – Derwent Park		✓	✓	✓
Terminus – Glenorchy	✓	✓	✓	✓
Journey Time	16.5 min	17 min	18min	19min
Service Frequency – Peak	15 min			
Service Frequency – Off Peak	30 min			
Core Bus Feeder Frequency – Peak	15 min			
Core Bus Feeder Frequency – Off Peak	30 min			
Peak Service Hours (LRT & Bus)	07:00 – 18:30			
Off Peak Service Hours (LRT & Bus)	06:00 – 07:00 and 18:30 – 19:30			
Saturday Service Hours (Off Peak)	08:00 – 19:00			
Sunday Service Hours (Off Peak)	09:00 – 18:00			

Table 6-7: *Core Optimal Operating Services Models*

The initial target for the OOSM options is establish a 15 minute frequency and determine the fastest end-to-end journey times using as few LRVs as possible with minimal infrastructure expenditure.

Each OOSM described below outlines the required number and location of crossing loops, number of LRV required and total travel time to complete the route. All OOSMs apart from OOSM 04 require three LRVs to operate the required timetable. OOSM 04 requires four LRVs. It is proposed that in case of vehicle failure an additional LRV may be required as a contingency. Alternatively, a replacement bus service could be provided in order to remove excessive LRV redundancy in the system during normal operation.

6.1 OOSM 1 – THREE STOP FAST SYSTEM

The initial OOSM concentrates on providing a fast service from Glenorchy to Hobart, with one intermediate stop at Moonah. In order to provide the target 15 minute service frequency, LRV's will need to pass each other twice during a typical peak journey. As shown in Figure 9-18, this can be achieved by constructing two passing loops (red option) or one loop, with duplicated tracks and platforms at Hobart CBD and Glenorchy Termini (green option).

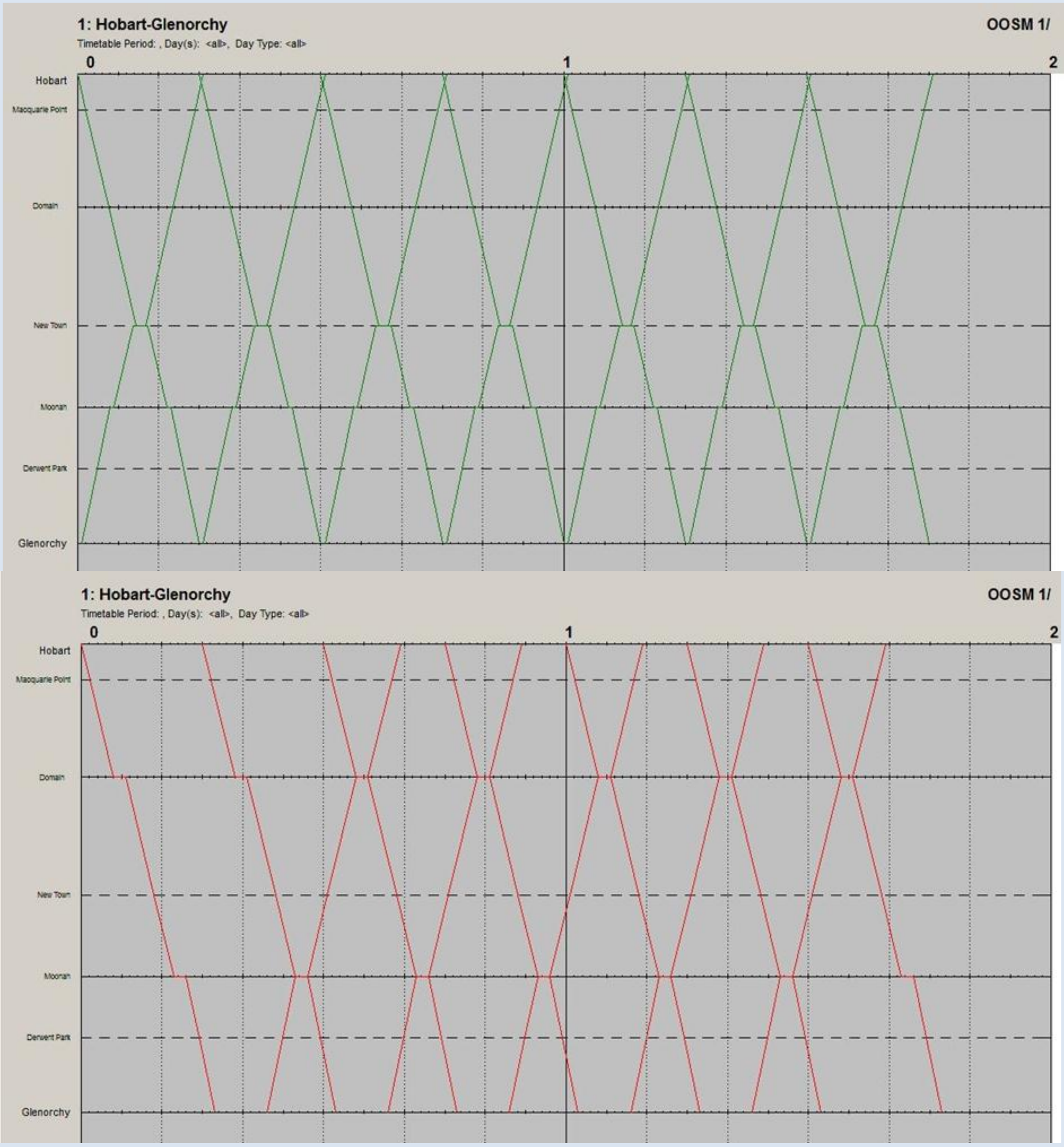

Figure 6-18 *OOSM 1 Train Graph Option with two passing loops (Red) and one passing loop (green) - From Plateway Report in Appendix A*

In order to minimise infrastructure and LRV expenditure, the two passing loop option (red) is preferred, as this can be operated with 3 LRV's and avoids the expense of duplicating the tracks in the termini.

Passing loops would be provided at Moonah, which would incorporate an island platform, and in the Domain area. The precise location of this loop will be determined at the detail design stage.

The current minimum travel time for this service is proposed as 16.5 minutes, which includes the time for LRVs to pass and passenger loading/unloading. In normal operating circumstances, it could be expected to turn the LRV around in as little as 2 minutes if required to make up time.

6.2 OOSM 2 – FOUR STOP NORTHERN FOCUS

The second OOSM developed is similar to OOSM 1, with an additional stop introduced at Derwent Park. This provides a further stop between Moonah and Glenorchy to deliver the service to all catchment areas at the northern end of the route.

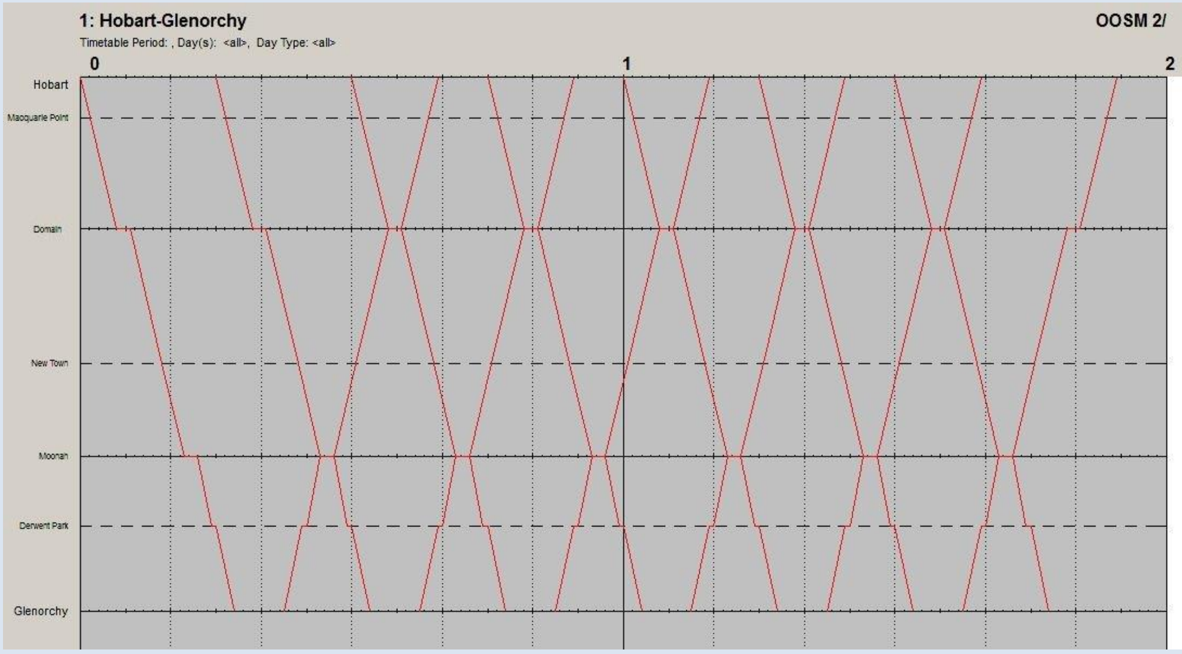

Figure 6-19: *OOSM 2 Train Graph – From Plateway Report in Appendix A*

The addition of the stop at Derwent Park as shown in **Figure 6-19** is absorbed by decreasing the turnaround time at Glenorchy, to 5 ½ minutes. The overall journey increases to 17 minutes.

Passing loops will be required at Domain and at the Moonah stop.

LRV operation and utilisation will be similar to OOSM 1, with a forth vehicle, or bus replacement required to provide cover during peak service.

6.3 OOSM 3 – FIVE STOP SUBURBAN FOCUS

OOSM 3 provides an additional stop New Town and all completes the service to all identified catchment zones in the northern suburbs.

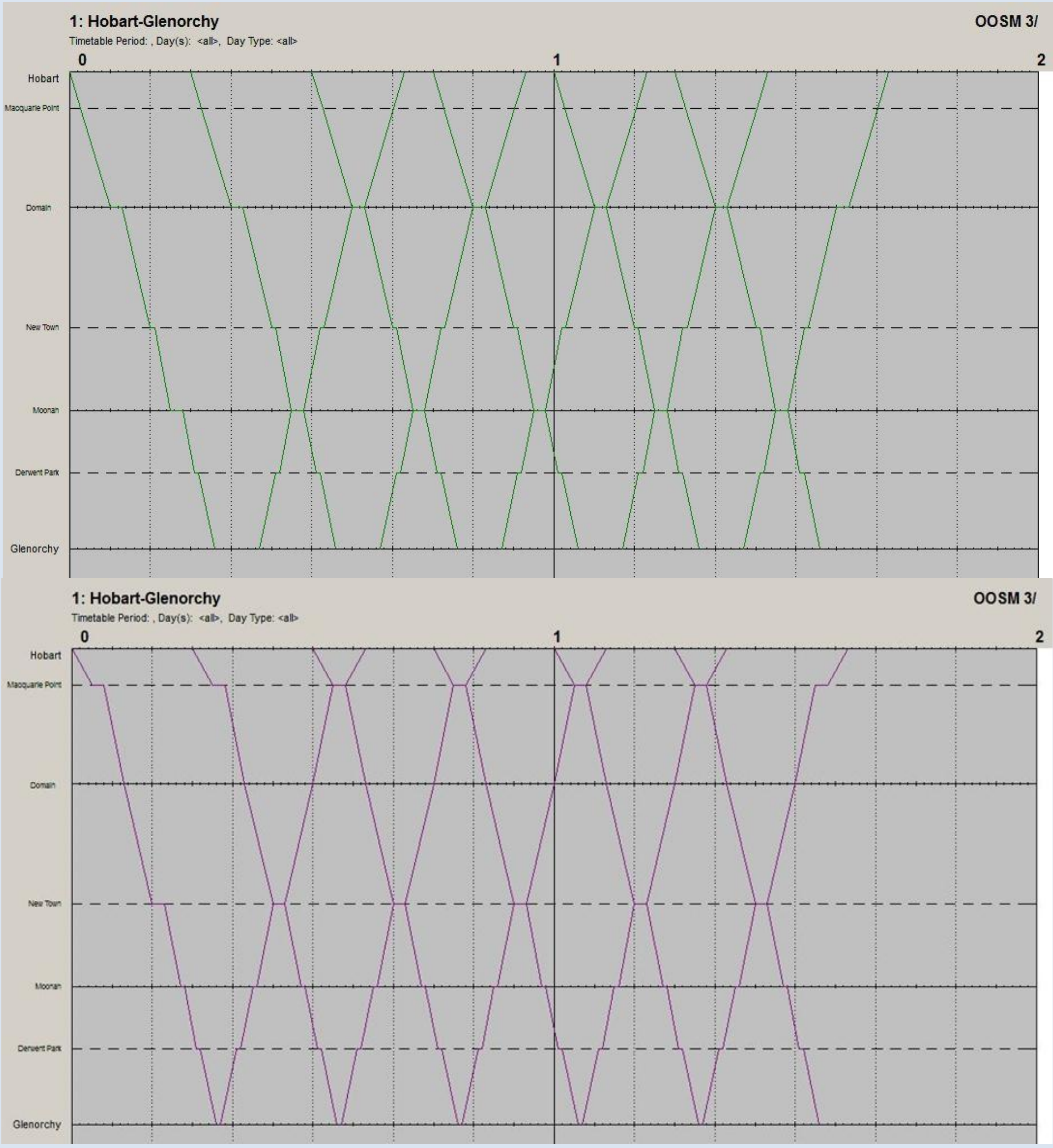

Figure 6-20: *OOSM 3 Train Graph Option with passing loops at Moonah and Domain (green), or Glenorchy, New Town and Macquarie Point (purple) – From Plateway Report in Appendix A*

The introduction of a stop at New Town increases journey time to 18 minutes and creates pressure on the turnaround time available at Hobart CBD, which is reduced to just 3 ½ minutes (green). This puts considerable strain on the reliability of the timetable, when using three vehicles. LRV priority within the CBD would be essential and functional at all times, but this would still not fully protect against unforeseen delays.

The location of the loop at Domain is also crucial, as the site shown in Figure 6-20 varies from that described in OOSM 1 and 2. It would be difficult to introduce a New Town stop at a later stage without extending or moving the passing loop, adding further cost.

A variation to OOSM 3 is shown in purple. This option requires four LRVs, two passing loops and two platform faces at Glenorchy. This will increase the cost of the project startup cost but does provide for greater flexibility and a more robust time table in the long term. Opportunities to develop this option from OOSM 1 or 2 are limited due to the loops being in a different location (New Town and Macquarie Point).

6.4 OOSM 4 – SIX STOP HIGH ACCESS FOCUS

OOSM 4 includes a stop at Macquarie Point, to service the future redeveloped site, which is close to the CBD and Hobart Terminus.

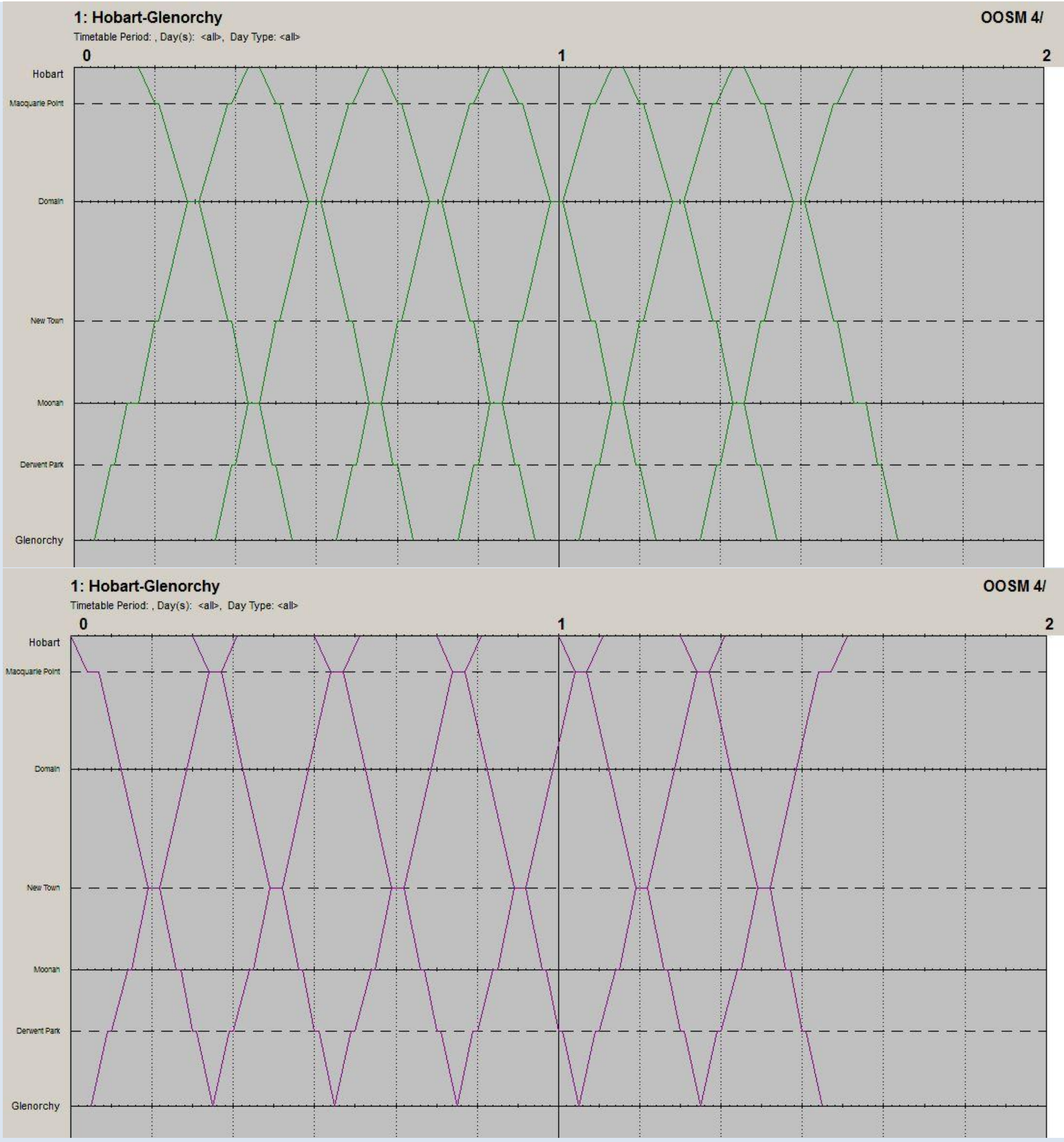

Figure 6-21: *OOSM 4 Train Graph Option with passing loops at Moonah and Domain (green) or Glenorchy, New Town and Macquarie Point (purple) – From Plateway Report in Appendix A*

Use of the 6 stops for OOSM 04 requires use of four LRVs and the location of the passing loop at Domain is not in the same place as the other OOSMs, therefore the expansion of the system will need to be considered with the initial introduction of the system. The travel time for OOSM 04 increases to 19 minutes.

This would require the introduction of a second platform face on Elizabeth Street, to allow services to cross. As a result, an LRV would have around 15 minutes waiting time in the CBD, which may have the additional attraction of providing suitable time to undertake a driver's break or changeover.

This option may be a suitable future development of OOSM 1 or 2, when patronage has increased and a fourth rail vehicle is required.

An alternative option (purple) avoids the need to provide two platform faces in Hobart CBD, but requires loops at Macquarie Point, New Town and two platform faces at Glenorchy. This option would also require four LRVs and would not be compatible as a future development of OOSM 1 or 2.

7 OOSM REVISED COST ESTIMATE

The cost estimates prepared and issued for the original OOSMs have been revised to consider design changes and likely construction variances to the original scheme. The main changes are outlined in the table below:

DESIGN / CONSTRUCTION CHANGE	COST ESTIMATE ADJUSTMENT
Reduced length of HLR, Glenorchy – Elizabeth Street	▪ Adjust distance and area based calculations accordingly ▪ Remove all costs associated with works north of Glenorchy (bridge and level crossing upgrades, etc.) ▪ Reduce number of LRV's required ▪ Reduce 5 year maintenance costs ▪ Reduce operational costs (less drivers, etc.)
Reduced number of stops in initial stage	▪ Reduce stop costs ▪ Reduce number of loops required
Extend HLR to Elizabeth Street from Mawson Place	▪ Increase street construction costs ▪ Increase allowance for traffic / pedestrian interface works ▪ Introduce allowance for intersection modification ▪ Additional allowance for service proofing
Incorporate dual/ standard gauge	▪ Increase clearing / stripping width ▪ Increase formation width and subgrade improvements ▪ Increase capping layer area ▪ Increase ballast quantities ▪ Allow for all provision of new track components throughout, no reuse assumed ▪ Reduce LRV purchase price ▪ Provide setup cost for future dual gauge if required
Use of 40m long Light Rail Vehicles	▪ Use of longer vehicles with larger capacity to cater for increased demand during peak periods
Annual Operational and Maintenance Costs	▪ Scaled reduction in staff numbers to suit reduced operations ▪ Maintenance budget adjusted to reflect reduced line distance.

Table 7-8: *Summary of Changes to the Cost Model*

There has been a reduction in the projected CAPEX cost of the project of 23% from $92.2m to $71.3m for the narrow gauge option. The route length has been reduced by around 40%, however some of the larger cost items such as the street construction in Hobart, electrification, bus interchange and the maintenance facility are still associated with the project.

The revised costs have been prepared using the same rates as the 2011 Business Case report, with a 5% allowance included for increase in construction costs. The construction cost is comparable to other existing cost data on similar track reconstruction projects, such as the Glenelg Tram Upgrade (2005). As the amount of street-running is relatively low (less than 1km), construction costs can be expected to be lower than other new light rail schemes proposed in Australia. A summary of the cost estimates are shown below, with the complete data included in Appendix B.

ITEM	VALUE ($AU)
OOSM 01 – Narrow Gauge CAPEX cost	$71,270,000
OOSM 01 – Standard Gauge CAPEX cost	$70,200,000
OOSM 02 – Narrow Gauge CAPEX cost	$71,643,000
OOSM 02 – Standard Gauge CAPEX cost	$70,572,000
OOSM 03 – Narrow Gauge CAPEX cost	$72.012,000
OOSM 03 – Standard Gauge CAPEX cost	$70,943,000
OOSM 04 – Narrow Gauge CAPEX cost	$79,713,000
OOSM 04 – Standard Gauge CAPEX cost	$77,976,000
Maintenance Costs, years 0-5	$ 505,300
Annual Operational Costs OOSM 01 to 03	$ 2,163,800
Annual Operational Costs OOSM 04	$ 2,478,800
Future additional dual gauge installation (optional to standard gauge costs if required)	*$ 2,751,000*

Table 7-9: *Summary of OOSM cost options*

8 CONCLUSION

This report represents a continuation of the work undertaken during the first stage of the project in 2011 and specifically covers Optimal Operating Service Models for a study area between Glenorchy and Hobart. Most of the study parameters and assumptions of the study undertaken in 2011 are the same and they have not been repeated in this report therefore this report must be read in conjunction with the 2011 report F0001-AA003945-AA01. The report can be read at: http://www.transport.tas.gov.au/miscellaneous/northern_suburbs_to_hobart_cbd_light_rail_business_case/what_is_stage_2

As a result of the consultation process and analysis during the project, four OOSM's have been developed as outlined in section 6 of this report.

In accordance with a preliminary assessment of the demand for a rail service this report considers provision of basic infrastructure to deliver cost effective solutions. Consequently the selection of options for the OOSMs targeted low cost solutions that provide comfort to passengers and comply with standard and safety requirements.

The key elements recommended in this report are summarised as follows:

- The existing track, although currently is used for freight, is deemed unsuitable for use as passenger rail in its current condition.
- The choice of gauge to be adopted will be dependent on the price and availability of any rolling stock at the time of construction. Based on construction costs alone, there are no significant savings by adopting standard gauge.
- The terminus in Hobart at this stage it is recommended to be at Franklin Square, on Elizabeth Street / Macquarie Street intersection.
- The most direct route should be adopted through the rail yards, with the possibility of amending the route in the future to accommodate the long term plan of the area.
- Suitable land for two tracks and two platform faces should be reserved through the rail yards
- The preferred configuration is a single line with passing loops.
- Electronic interlocking signalling system is recommended to be introduced.
- OHW electrification is the recommended option to be considered at this stage.
- Vehicles should preferably be substantially low floor, with a minimum length of 40m to achieve capacity requirements.

Cost estimates have been developed for the OOSMs and the alternative options that have been considered in this report.

APPENDIX A – RAIL SIMULATION

Plateway

Hobart Light Rail Study II

For

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Version	Date	Author/Reviewer	History
1	04/04/2013	D. Lewis	Draft for client review
2	30/04/2013	D. Lewis	Revision 1

Plateway

Table of Contents

Hobart Light Rail

In 2011 Plateway Pty Ltd undertook an exercise on behalf of Hyder Consulting using the OpenTrack rail simulation software to create a model of the proposed Hobart to Claremont light rail line. This was then used to develop a series of scenarios that sought to provide some indication of the rolling stock requirements to operate a light rail service.

In this current undertaking, Plateway are again using OpenTrack modelling techniques to develop an understanding of what service optimal operating patterns might be achievable for light rail transit (LRT) over the section of line between Hobart and Glenorchy. The original OpenTrack model was modified using data supplied by Hyder Consulting and then the results of simulations performed were used as the basis for an LRT operating plan.

The model was created from curve and gradient data along with additional information provided by Hyder. In addition to the alignment that would be resumed from the Hobart to Glenorchy heavy railway right of way; the model also extends the route some 700 metres from the current old Hobart heavy railway terminus into the city of Hobart to arrive at Elizabeth Street. The OpenTrack assumptions and outcomes are shown in the tables below.

The OpenTrack data was interpreted and developed as the basis for a regular interval timetable service using the SMA+ Viriato timetable software. The regular interval headway used as the base case was 15 minutes. Four Optimal Operating Service Model (OOSM) scenarios were then used to make comparisons between different stopping patterns. From this it was possible to gain some insight into infrastructure needs and the amount of rolling stock required to operate a basic LRT service. No assumptions were made about demand.

Assumptions

The line is currently a single, non-electrified, heavy railway (nominally used for freight only services). It is assumed that the right of way will be rebuilt to allow electric LRT vehicles (and heritage heavy rail passenger equipment) to operate at a maximum line speed of 80 kph.

The final route used for modelling and timetable development purposes was that between Glenorchy and Elizabeth Street. For the purpose of this exercise it was considered that, assuming the city terminus was not shifted substantially, the city terminus of this model would give a consistent picture of requirements across multiple scenarios.

No assumptions were made about operational parameters such as adopted systems of safeworking. Practices adopted in the future may impact the operations of this line and affect the outcome of this model. It was assumed a certain amount of time was required for two opposing vehicles to cross each other on the single line, no priority was given to either direction and LRT vehicles were allowed the same amount of time to cross. In the future it may be found that vehicles can cross in shorter periods or only the LRT vehicle taking the loop requires additional crossing time. This could lead to greater levels of robustness in the less reliable scenarios.

Additionally it was assumed LRT vehicles were afforded a high (or first) level of priority at level crossings and in street running. For this purpose it was assumed that LRT vehicles entering the shared street running from the dedicated right of way receive a no-delay priority and that they also receive this priority at traffic lights. A low speed of 30 kph in all shared areas was applied in the model to simulate this priority.

LRT rolling stock for use on these services is expected to be derived from existing overhead electric powered proven and available technology, capable of operating in coupled multiple units (if required) and driven from either end of the vehicle. It was assumed that this equipment can operate on a dual use (heavy and light) rail profile. The vehicle type adopted for the modelling exercise was the Flexity Tram by Bombardier (as used by Adelaide Metro).

Sectional run times (SRT) were generated in the OpenTrack model to use as the basis for a timetable. These times (shown for each OOSM below) are rounded to create a timetable. For convenience of both operators and the travelling public, timetables are developed around 30 second intervals, with only whole minutes made available in public timetables.

The SRT data was generated on the following assumptions:

Train Driving Style	
Max. Tractive Effort	95%
Braking Method	Dynamic
Braking Rates	Flexity: -0.6m/s^2
Other Handling Assumptions	Normal

Train Characteristics - Technical	
Resistance Factor (Strahl Formula)	3.2999 (Flexity)
Rotating Mass	1.0599 (Flexity)

Signalling & Safeworking	
Safeworking System	Not determined (single track with loops)
Default Signal Sighting Distance	5,000m
Train Operation Rules	N/A (single LRV only)
Priority Rules (if any)	LRV (single consist)
Road Reservation (Sections)	Assumed LRV priority
Speed Board Treatment	End of LRV clears speed board before accelerating
Line Speed	60 kph

All models ran at 95% performance in order to more closely resemble human behaviour and equipment performance.

No robustness testing was carried out.

Definitions

OOSM – Optimal Operating Service Model, used as the basis for each test scenario.

DLRV – Diesel Light Rail Vehicle, based on existing Kiwirail ADK-ADB narrow gauge railcars. A current light rail equivalent would include, for example, the Stadler GTW diesel powered light rail vehicles, suitable for operation on lightly laid rail and for street running. DLRV were not considered in this exercise.

LRV – Electric Light Rail Vehicle, equivalent to, for example, the Bombardier Flexity family overhead electrically powered light rail vehicle, suitable for operation on lightly laid rail and for street running.

OT – OpenTrack rail system modelling software.

SRT – Sectional Run Times, derived from the Open Track model. The time taken to complete each nominated section of track including stopping and starting from each passenger halt.

Dwell time – Nominated time at each intermediate stop taken to allow for the loading/unloading of passengers. The dwell times used in this study are 30 seconds, considered an industry based average.

Disturbance conditions - Operations when services are running late, have extended dwell or cross times, have some sort of equipment or human resource delay or failure, are subject to restricted running .e.g. lower speed limits, and so on.

Recovery time - Time allowed in the timetable for a vehicle in service to recover to the timetable. Recovery times are usually built into timetables in running times between stops, in stop dwell times or in time allowed at turnbacks. As the former two are important in this exercise, the turnback time has been chosen as the place in which to build most of the recovery time. (Because the nature of safeworking at loops has not yet been defined, it is hard to place an accurate figure on this in the indicative timetable).

Line Speed

Although the reconstructed line would have a maximum permissible speed of 80 kph, the maximum line speed used in the modelling scenarios as set at 70 kph and was as low as 60 kph. Prior to assessing the specific OOSM scenarios adopted, an assessment was made of the effects of raising the line speed and removing a number of more restrictive curve speeds. A summary of the outcomes of these tests are shown in the two tables below:

Five iterations were made and SRT information recorded. This table shows the number of seconds taken for each iteration.

	Iteration 0	Iteration 1	Iteration 2	Iteration 3	Iteration 3a
Outbound	805	873	855	842	768
Inbound	801	866	847	836	762

Percentage change in time (factor of improvement) (calculated for outbound only)

(Time) Percentage Improvement Factor over Iteration 1			
Iteration 1	Line speed 60 kph, curve speed restrictions on dedicated right of way	873	0%
Iteration 2	Line speed 65 kph, curve speed restrictions on dedicated right of way	855	2.11%
Iteration 3	Line speed 70 kph, curve speed restrictions on dedicated right of way	842	3.68%
Iteration 0	Line speed 60 kph, no speed restrictions on dedicated right of way	805	8.45%
Iteration 3a	Line speed 70 kph, no speed restrictions on dedicated right of way	768	13.67%

These times were taken prior to the chainage change for proposed stop location distances.

The results suggest that greater improvements to infrastructure especially curve speed restrictions will be more beneficial than an increase in the overall line speed. In modern vehicles it is unlikely that a top line speed over 60 kph and up to 70 kph will have any appreciable effect on passenger comfort because of ride characteristics.

The times used in the OOSM models that follow took account of a minor change to stop location chainage as advised by Hyder.

Proposed Operating Plans

The Department of Infrastructure, Energy and Resources provided information for four conceptual Optimal Operating Service Models (OOSMs) which varied the number of stops required (and therefore impacted the required infrastructure and equipment). The outcome of modelling each of these OOSMs is detailed in the sections that follow.

OOSM1

All other assumptions being as above, OOSM1 was used to assess an operating service model that had just three passenger stops: Hobart, Moonah and Glenorchy.

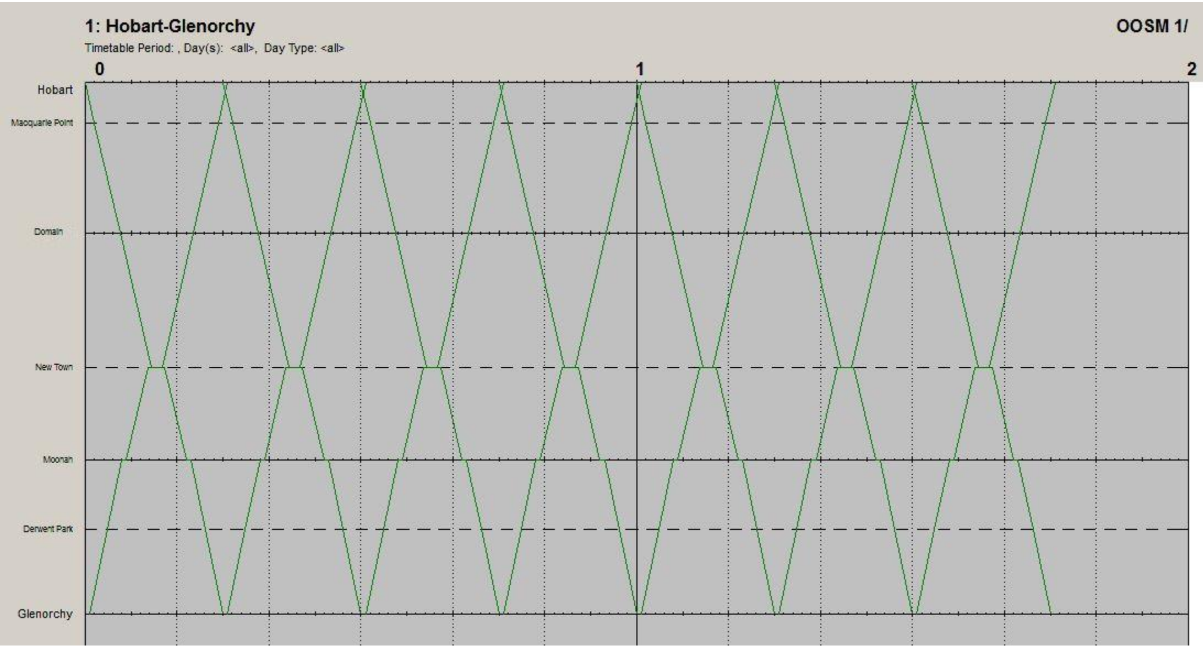
OOSM1 (3 stops - Glenorchy, Moonah, Hobart) Performance 95%

	Km		Time	Time (sec)	Time Between Points	Time Between Points (sec)	**Viriato Run Times**
HOBART (Elizabeth Street)	0	Dep.	0:00:00	0	0:00:00	0	0
MACQUARIE POINT		Pass	0:01:52	112	0:01:52	112	
MACQUARIE POINT							
DOMAIN		Arr.					4
DOMAIN		Dep.					1.5
NEWTOWN	5.14	Pass	0:07:44	464	0:05:52	352	
NEWTOWN							
MOONAH	6.57	Arr.	0:09:30	570	0:01:46	106	6
MOONAH		Dep.	0:10:00	600	0:00:30	30	1.5
DERWENT PARK	7.66	Pass	0:11:14	674	0:01:14	74	
DERWENT PARK						30	
GLENORCHY	9.16	Arr.	0:13:06	786	0:01:52	112	3.5
Total							16.5
GLENORCHY	9.16	Dep.	0:30:01	1801	0:00:00	0	0
DERWENT PARK	7.66	Pass	0:31:38	1898	0:01:37	112	
DERWENT PARK						30	
MOONAH	6.57	Arr.	0:33:09	1989	0:01:31	91	3.5
MOONAH		Dep.	0:33:39	2019	0:00:30	30	1.5
NEWTOWN	5.14	Pass	0:35:08	2108	0:01:29	89	
NEWTOWN							
DOMAIN		Arr.					6
DOMAIN		Dep.					1.5
MACQUARIE POINT		Pass	0:41:00	2460	0:05:52	352	
MACQUARIE POINT							
HOBART (Elizabeth Street)	0	Arr.	0:43:03	2583	0:02:03	123	4
							16.5

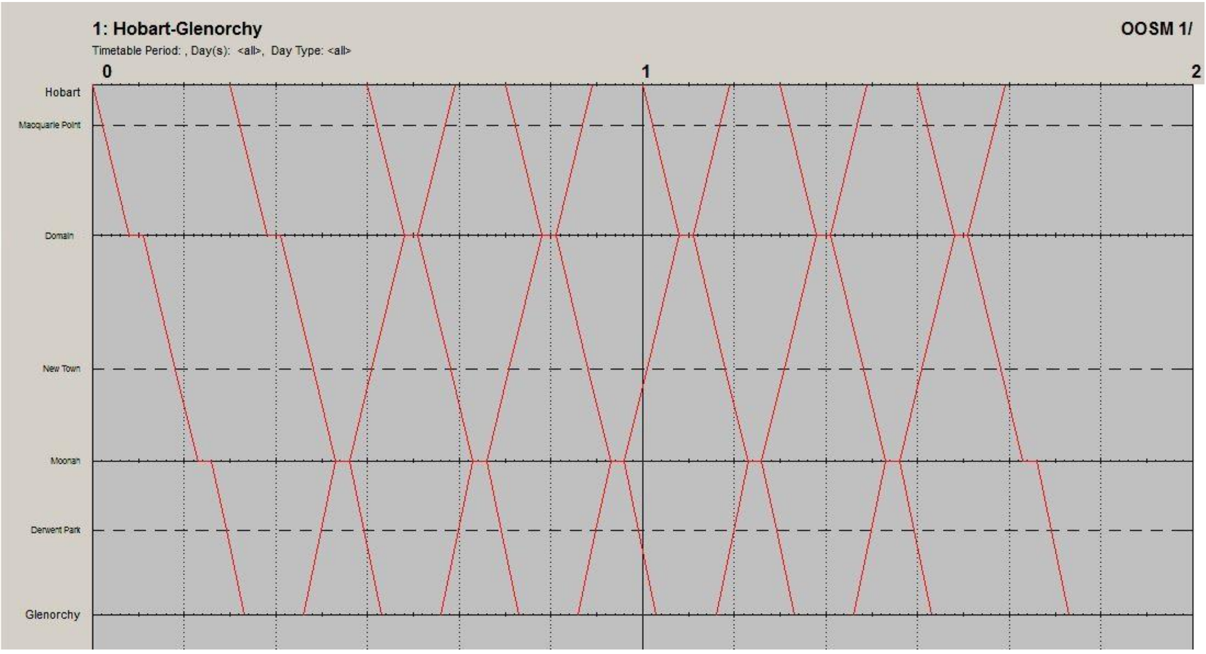
OOSM1 Commentary

The times above (and for all other OOSMs) were derived with performance set at 95%. These times were derived after a change of stop chainage (as advised by Hyder) so may differ in some detail from the results used for the infrastructure comparisons explained above.

The diagram below indicates that Newtown is the natural half way point but running times combined with the frequency (headway) do not permit the use of a single crossing loop on this single track LRT system.



OOSM 1: Optimised operational pattern.

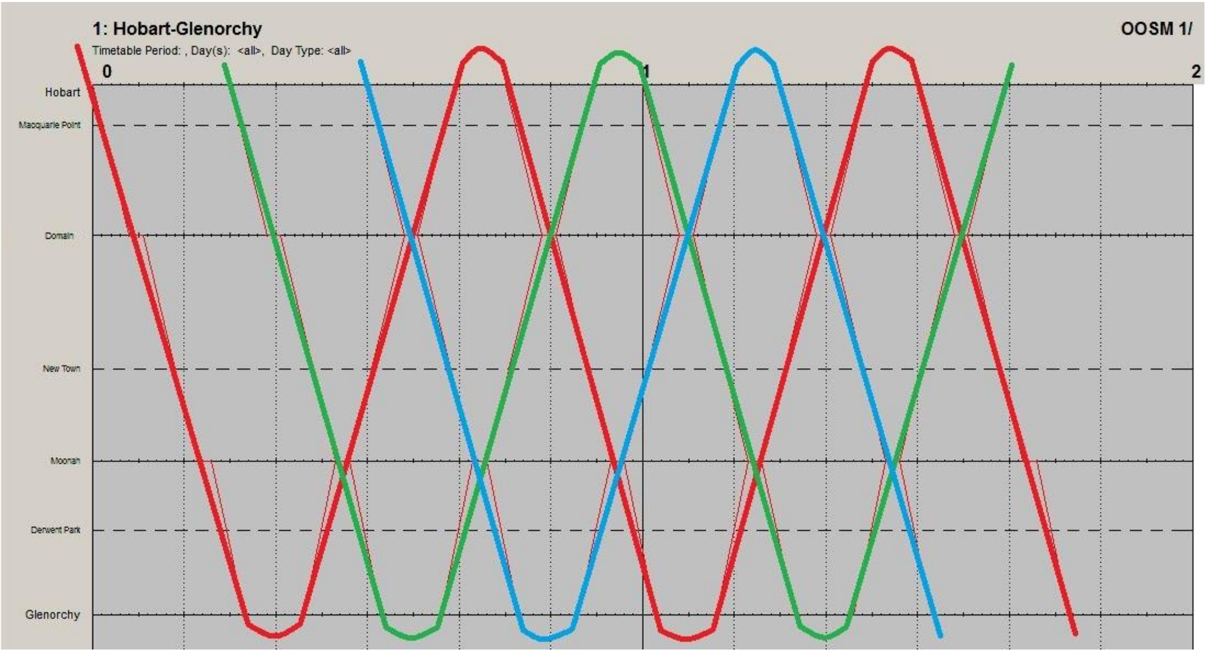


The diagram above represents a best fit indicative service proposal based on the parameters provided. These parameters include Flexity type tram vehicle, operating to a maximum line speed of 60 kph, slowing for curves on the dedicated right of way, stopping only at crossing points and the one intermediate stop, with a 15 minute frequency (headway).

It would require a minimum of two crossing loops, one at Moonah to coincide with the passenger stop, and another at an undefined point described as Domain. The precise location of this loop could be modelled at a future date; its location is dependent on final terminus plans and other influences.

Plateway

Equipment Utilisation:



The diagram for equipment deployment above demonstrates that three vehicles would be the minimum required to operate this level of service. A contingency plan in the case of disturbance to normal operations would be reliant on bus substitution, e.g. if one vehicle was out of service.

With three vehicles there is no possibility of improving frequency without a substantial reduction in running times. The current minimum travel time for this service is proposed as 16.5 minutes, which includes the time for crosses and passenger loading/unloading. The times are based on rounded up times for 95% performance of the vehicles and the drivers, there is no recovery time other than what could be achieved in the actual crosses (allowed 1.5 minutes) and in the turnarounds (5.5 minutes at Hobart, 6.5 minutes at Glenorchy). Ordinarily with an LRT of this type you should be able to turn it back in around 2 minutes under disturbance conditions.

Reliability will be strengthened by providing 4 vehicles, as well as it allowing more versatility in meeting short term demand (e.g. for peak periods or for special events) or for making corrections under disturbance conditions.

OOSM2

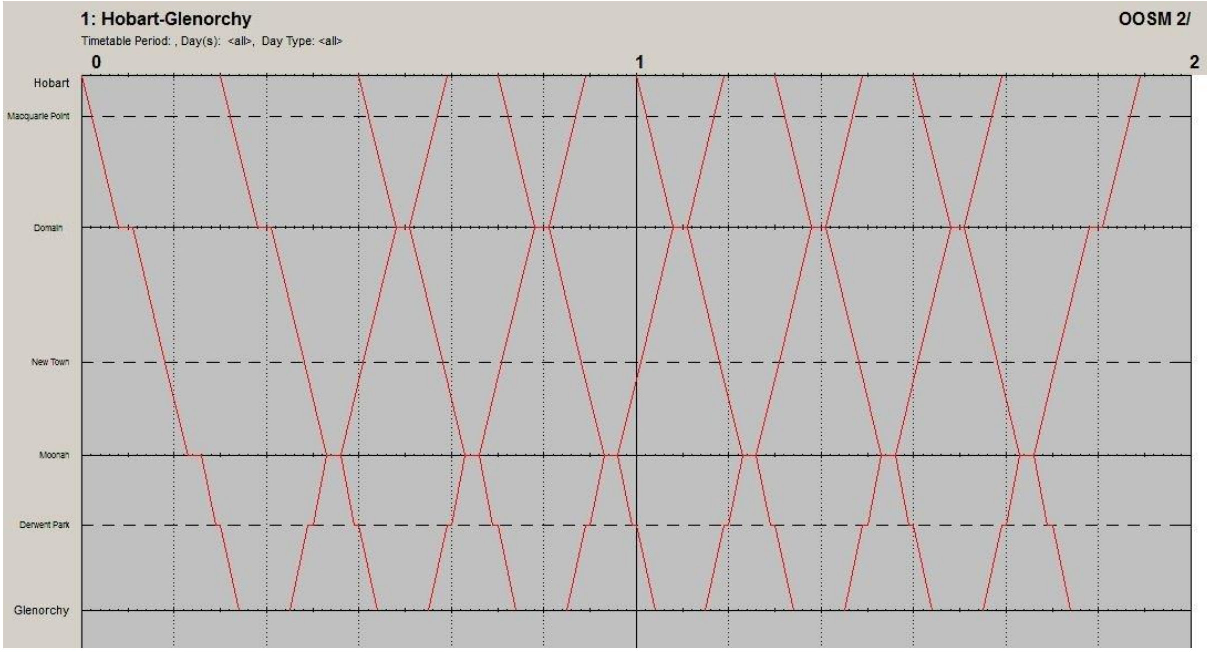
All other assumptions being as above, OOSM2 was used to assess an operating service model that had four passenger stops: Hobart, Moonah, Derwent Park and Glenorchy.

OOSM2 (4 stops - Glenorchy, Derwent Park, Moonah, Hobart) Performance 95%

	Km		Time	Time (sec)	Time Between Points	Time Between Points (sec)	**Viriato Run Times**
HOBART (Elizabeth Street)	0	Dep.	0:00:00	0	0:00:00	0	0
MACQUARIE POINT		Pass	0:01:52	112	0:01:52		
MACQUARIE POINT							
DOMAIN							4
DOMAIN							1.5
NEWTOWN	5.14	Pass	0:07:44	464	0:05:52	457	
NEWTOWN						30	
MOONAH	6.57	Arr.	0:09:30	570	0:01:46	106	6
MOONAH		Dep.	0:10:00	600	0:00:30	30	1.5
DERWENT PARK	7.66	Arr.	0:11:34	694	0:01:34	90	1.5
DERWENT PARK		Dep.	0:12:04	724	0:00:30	30	0.5
GLENORCHY	9.16	Arr.	0:13:56	836	0:01:52	107	2
							17
GLENORCHY	9.16	Dep.	0:30:01	1801	0:00:00	0	0
DERWENT PARK	7.66	Arr.	0:31:53	1913	0:01:52	112	2
DERWENT PARK		Dep.	0:32:23	1943	0:00:30	30	0.5
MOONAH	6.57	Arr.	0:33:59	2039	0:01:36	96	1.5
MOONAH		Dep.	0:34:29	2069	0:00:30	30	1.5
NEWTOWN	5.14	Pass	0:35:58	2158	0:01:29	89	
NEWTOWN							
DOMAIN							6
DOMAIN							1.5
MACQUARIE POINT		Pass	0:41:50	2510	0:05:52	352	
MACQUARIE POINT							
HOBART (Elizabeth Street)	0	Arr.	0:43:53	2633	0:02:03	123	4
							17

OOSM2 Commentary

OOSM2: Optimised Operational Pattern



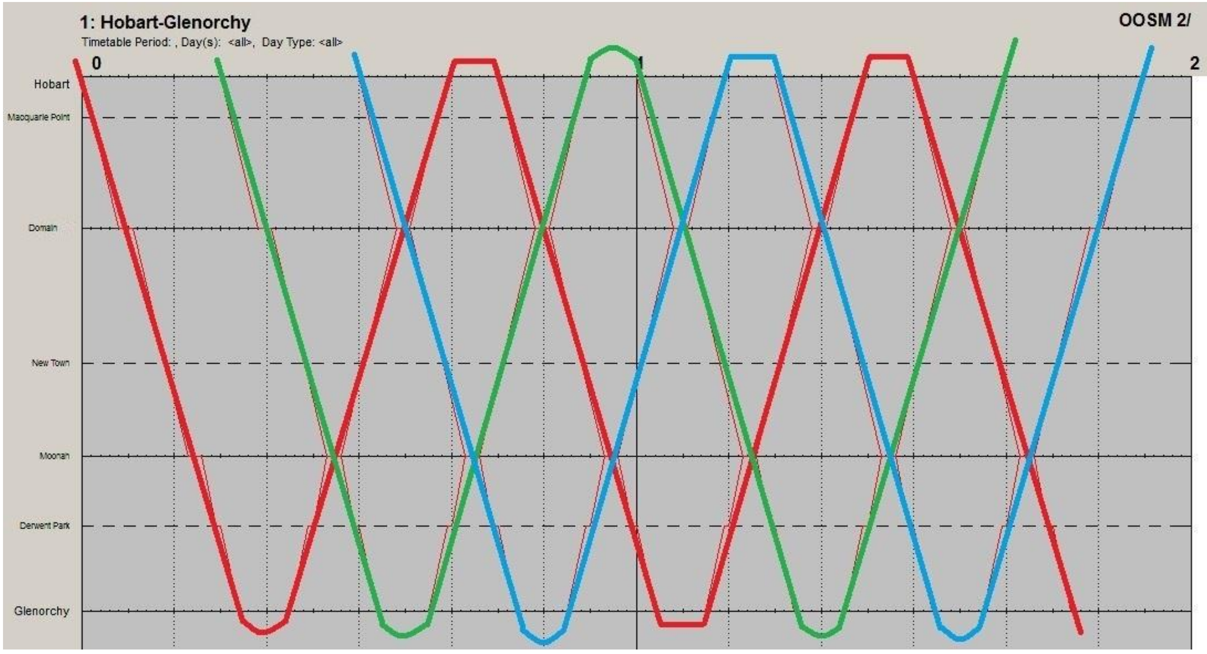
The diagram above displays a pattern not unlike OOSM1 and represents a best fit indicative service proposal based on the parameters provided.

The only significant difference that the additional stop at Derwent Park makes is to slightly lengthen running times and add dwell time.

Importantly it impacts on the turnaround time at Glenorchy shortening it slightly to 5.5 minutes.

This option requires a minimum of two crossing loops, one at Moonah to coincide with the passenger stop, and another at the undefined point described as Domain.

Equipment Utilisation:



The diagram for equipment deployment above demonstrates that three vehicles would be the minimum required to operate this level of service. Again the same contingency and disturbance issues arise, accentuated with the reduction in turnaround recovery time.

There is no scope to improve headways with this stopping pattern and this number of vehicles.

As one adds more stops, then the issue of reliability in using only three vehicles will become exacerbated.

Reliability will be strengthened by providing 4 vehicles, as well as allow more versatility in meeting short term demand or for making corrections under disturbance conditions.

OOSM3

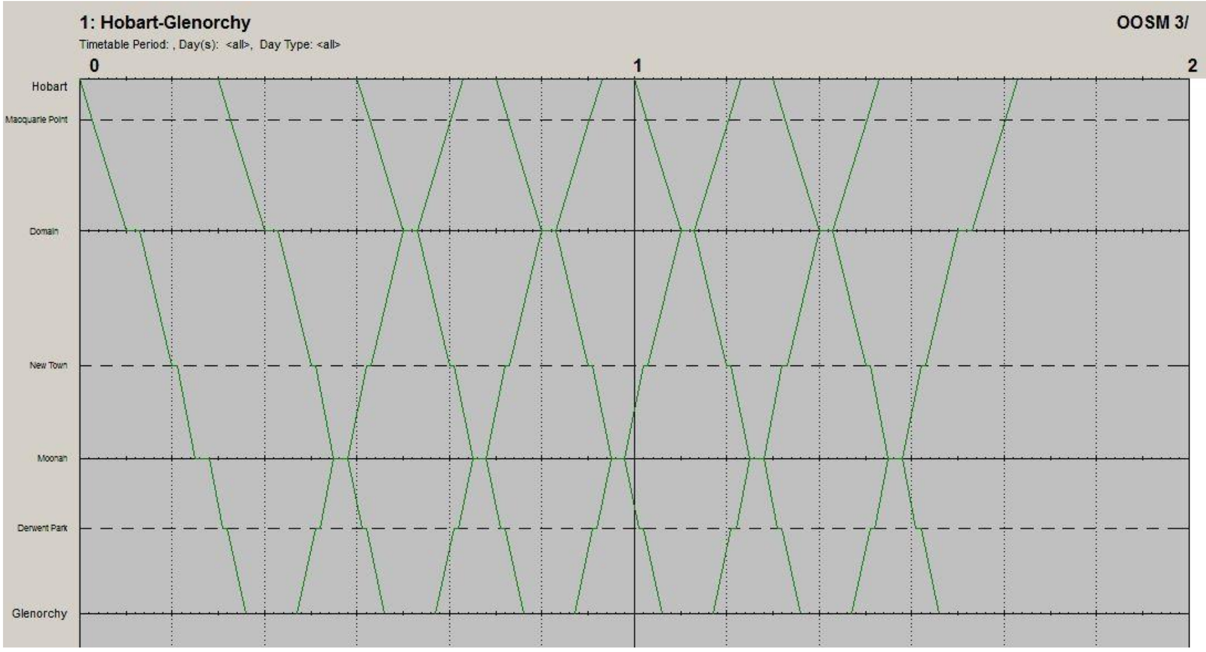
All other assumptions being as above, OOSM3 was used to assess an operating service model with five stops: Hobart, Newtown, Moonah, Derwent Park and Glenorchy.

OOSM3 (5 stops – Glenorchy, Derwent Park, Moonah, Newtown, Hobart) Performance 95%

	Km		Time	Time (sec)	Time Between Points	Time Between Points (sec)	**Viriato Run Times**
HOBART (Elizabeth Street)	0	Dep.	0:00:00	0	0:00:00	0	0
MACQUARIE POINT		Pass	0:01:52	112	0:01:52	112	
MACQUARIE POINT							
DOMAIN							4.5
DOMAIN							1.5
NEWTOWN	5.14	Arr.	0:07:59	479	0:06:07	367	4
NEWTOWN		Dep.	0:08:29	509	0:00:30	30	0.5
MOONAH	6.57	Arr.	0:10:20	620	0:01:51	111	2
MOONAH		Dep.	0:10:50	650	0:00:30	30	1.5
DERWENT PARK	7.66	Arr.	0:12:24	744	0:01:34	94	1.5
DERWENT PARK		Dep.	0:12:54	774	0:00:30	30	0.5
GLENORCHY	9.16	Arr.	0:14:46	886	0:01:52	112	2
							18
GLENORCHY	9.16	Dep.	0:30:01	1801	0:00:00	0	0
DERWENT PARK	7.66	Arr.	0:31:53	1913	0:01:52	112	2
DERWENT PARK		Dep.	0:32:23	1943	0:00:30	30	0.5
MOONAH	6.57	Arr.	0:33:59	2039	0:01:36	96	1.5
MOONAH		Dep.	0:34:29	2069	0:00:30	30	1.5
NEWTOWN	5.14	Arr.	0:36:30	2190	0:02:01	121	2
NEWTOWN		Dep.	0:37:00	2220	0:00:30	30	0.5
DOMAIN							4.5
DOMAIN							1.5
MACQUARIE POINT		Pass	0:42:39	2559	0:05:39	339	
MACQUARIE POINT							
HOBART (Elizabeth Street)	0	Arr.	0:44:42	2682	0:02:03	123	4
							18

OOSM3 Commentary

OOSM3: Optimised operational pattern Option 1.



The diagram above represents a best fit indicative service proposal based on the parameters provided, and in line with the models OOSM1 and OOSM2.

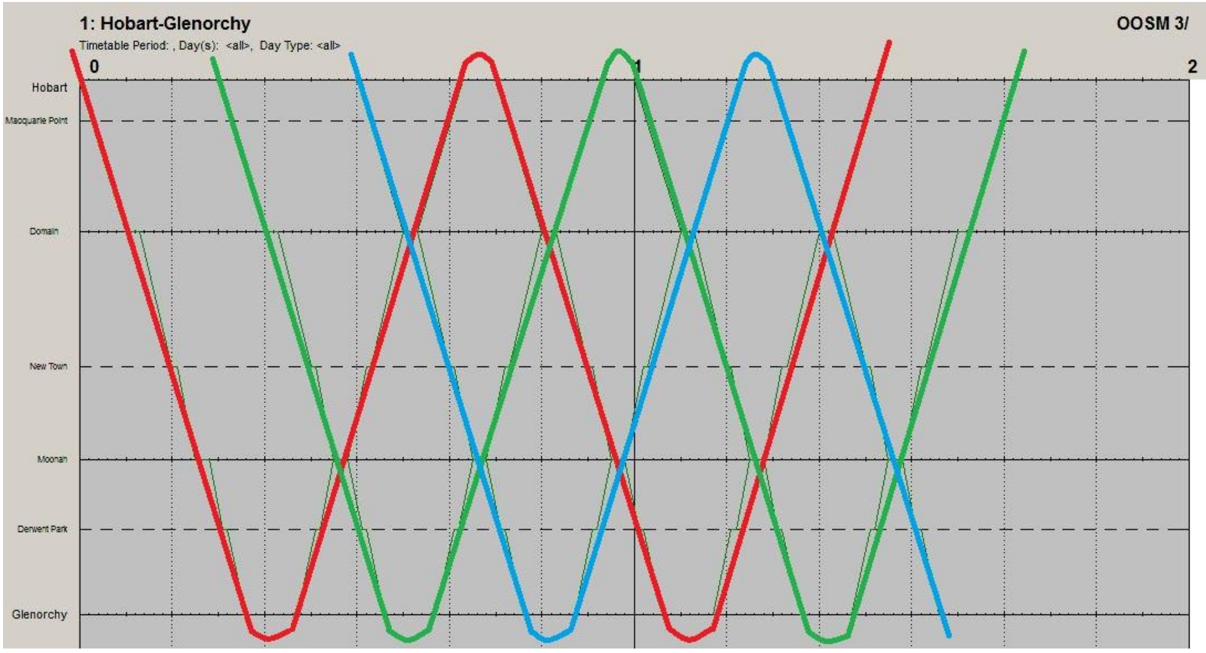
The addition of a passenger stop at Newtown impacts on the timetable model in two significant areas – it influences the actual physical location of the Domain passing loop and reduces the turnaround times at the Hobart end.

For the purpose of the model, the location of the Domain loop is not fixed as it is a notional location used for crossing services on the single line. As this is an infrastructure asset that for the model can be adjusted to suit the service pattern, the physical location would be different to that proposed in the preceding models OOSM1 and OOSM2. Domain loop would now be located closer toward Newtown and its precise location would require further refinement.

A decision about service levels in the medium to long term must be made before a commitment is made as to where to place the Domain loop.

A more critical issue is what is left in turnaround times. Although this service pattern can be superficially achieved with 3 vehicles, its reliability and ability to recover is deteriorating. Although the Glenorchy terminus still has 5.5 minutes in turnaround, the Hobart end is down to 3.5 minutes. There is no recovery time in actual running times, so if a service is delayed en-route it must make its recovery in the time available at the termini.

Equipment Utilisation:



The diagram above for equipment deployment demonstrates that three vehicles would be the minimum required to operate this level of service. Again the same contingency and disturbance issues arise, accentuated further than before through the reduction in turnaround recovery time.

Operating this option under the current assumptions with only three vehicles is not recommended. The timetable provides turnaround times of only 3.5 minutes at Hobart and 5.5 minutes at Glenorchy. Even limited delays in street running at the Hobart end would disrupt this timetable, although the extent of risk factors has not been assessed in this study.

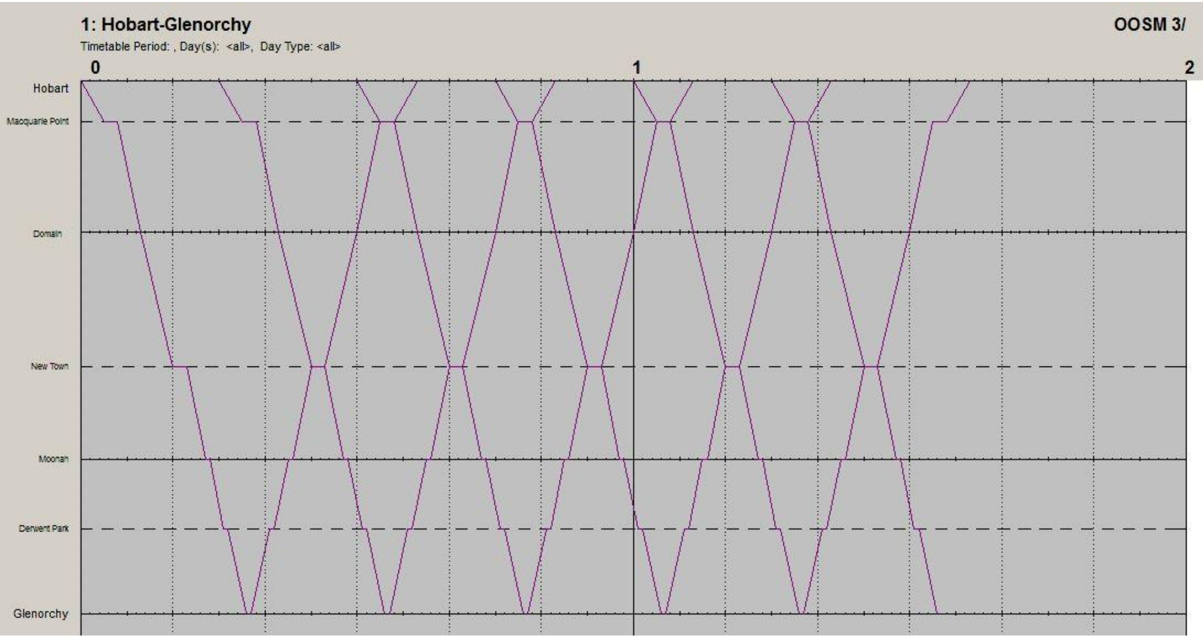
If the consistent modelling assumptions were varied then this option may become more reliable. The two pertinent assumptions relate to the model of the line speed and crossing times. If the line speed in the model was raised to 80 kph then this would improve running time marginally. If priority at crossing loops was afforded to inbound (toward Hobart) LRT vehicles then this would lead to a marginal improvement in running times. Both of these margins would make this OOSM more reliable and predictable.

None-the-less, serious consideration would need to be given to delay prevention, such as priority at traffic lights and separation in shared zones so as to reduce the risk of unrecoverable disruption to the service pattern.

Unrecoverable disruption alludes to the idea that individual services cannot recover from disruption, resulting in service cancellation or truncation or other drastic steps to recover the timetable.

OOSM3: Optimised operational pattern Option 2.

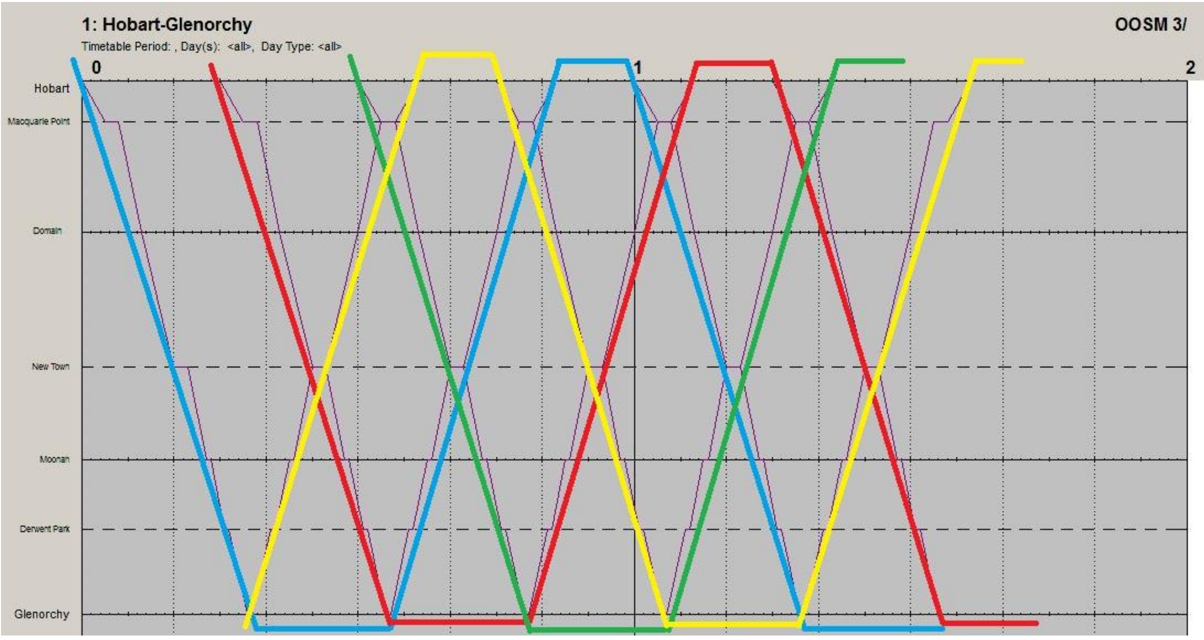
Given that stakeholders indicated a preference to a 15 minute interval service with 5 stops, an exercise was undertaken to determine if a more robust operating scenario involved the provision of a third crossing loop. Although this introduces further capital cost and increases running times (through delays in having to make three crosses instead of two) it does creates a more flexible layout in times of disruption.



The service pattern represented by the diagram above centres around crossing loops at Macquarie Point and Newtown rather than Moonah and Domain. It would require that the Macquarie Point crossing loop be located a little further west than that proposed in OOSM4 (at approximately the 0.740 km mark), but presumably still comfortably within the redevelopment area.

This pattern would also require additional infrastructure be provided at Glenorchy so as to allow an LRV to layover whilst the other exits the terminus. This would provide 3 segments of "substantial" infrastructure, but given the need to consider a depot location, and its likelihood of co-location at the Glenorchy terminus, the provision of a second track and platform at Glenorchy should not represent a major change in infrastructure costs.

Equipment Utilisation:



The turnaround times at Hobart are generous in this pattern at 8.5 minutes and the turnaround times at Glenorchy are 15.5 minutes. This makes this timetable lower risk and less susceptible to unrecoverable disruption.

To operate this pattern would require a minimum of four vehicles. It demonstrates how sensitive to change the timetable becomes as journey time extends. However it also demonstrates that a more robust timetable is able to be considered with more equipment.

OOSM4

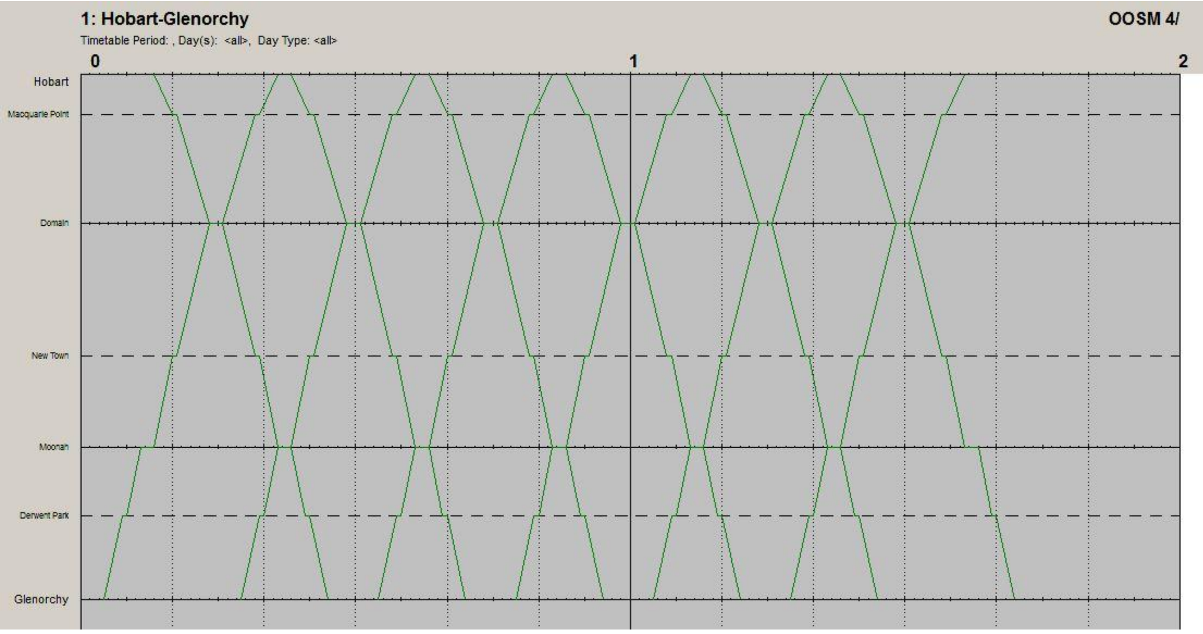
All other assumptions being as above, OOSM4 was used to assess an operating service model with six stops: Hobart, Macquarie Point, Newtown, Moonah, Derwent Park and Glenorchy.

OOSM4 (6 stops – Glenorchy, Derwent Park, Moonah, Newtown, Macquarie Point, Hobart) Performance 95%

	Km		Time	Time (sec)	Time Between Points	Time Between Points (sec)	**Viriato Run Times**
HOBART (Elizabeth Street)	0	Dep.	0:00:00	0	0:00:00	0	0
MACQUARIE POINT		Arr.	0:02:03	123	0:02:03	123	2
MACQUARIE POINT		Dep.	0:02:33	153	0:00:30	30	0.5
							3
							1.5
NEWTOWN	5.14	Arr.	0:08:39	519	0:06:06	366	4
NEWTOWN		Dep.	0:09:09	549	0:00:30	30	0.5
MOONAH	6.57	Arr.	0:11:00	660	0:01:51	111	2
MOONAH		Dep.	0:11:30	690	0:00:30	30	1.5
DERWENT PARK	7.66	Arr.	0:13:04	784	0:01:34	94	1.5
DERWENT PARK		Dep.	0:13:34	814	0:00:30	30	0.5
GLENORCHY	9.16	Arr.	0:15:26	926	0:01:52	112	2
							19
GLENORCHY	9.16	Dep.	0:30:01	1801	0:00:00	0	0
DERWENT PARK	7.66	Arr.	0:31:53	1913	0:01:52	112	2
DERWENT PARK		Dep.	0:32:23	1943	0:00:30	30	0.5
MOONAH	6.57	Arr.	0:33:59	2039	0:01:36	96	1.5
MOONAH		Dep.	0:34:29	2069	0:00:30	30	1.5
NEWTOWN	5.14	Arr.	0:36:30	2190	0:02:01	121	2
NEWTOWN		Dep.	0:37:00	2220	0:00:30	30	0.5
							4
							1.5
MACQUARIE POINT		Arr.	0:42:50	2570	0:05:50	350	3
MACQUARIE POINT		Dep.	0:43:20	2600	0:00:30	30	0.5
HOBART (Elizabeth Street)	0	Arr.	0:45:21	2721	0:02:01	121	2
							19

OOSM4 Commentary

OOSM4: Optimised operational pattern Option 1.



The final scenario – OOSM4 - uses the previous parameters but with 6 stops. This option continues to centre infrastructure about Domain and Moonah. Again the Domain loop would be located in a timetable optimum location and would not be located in the same place as that used for any of the preceding OOSMs.

Given the preference in the first instance for operating the stopping pattern of OOSM3, but the likelihood of needing to operate a pattern based on OOSM4 in the longer term, it would be necessary to consider the location of Domain crossing loop in the light of OOSM4.

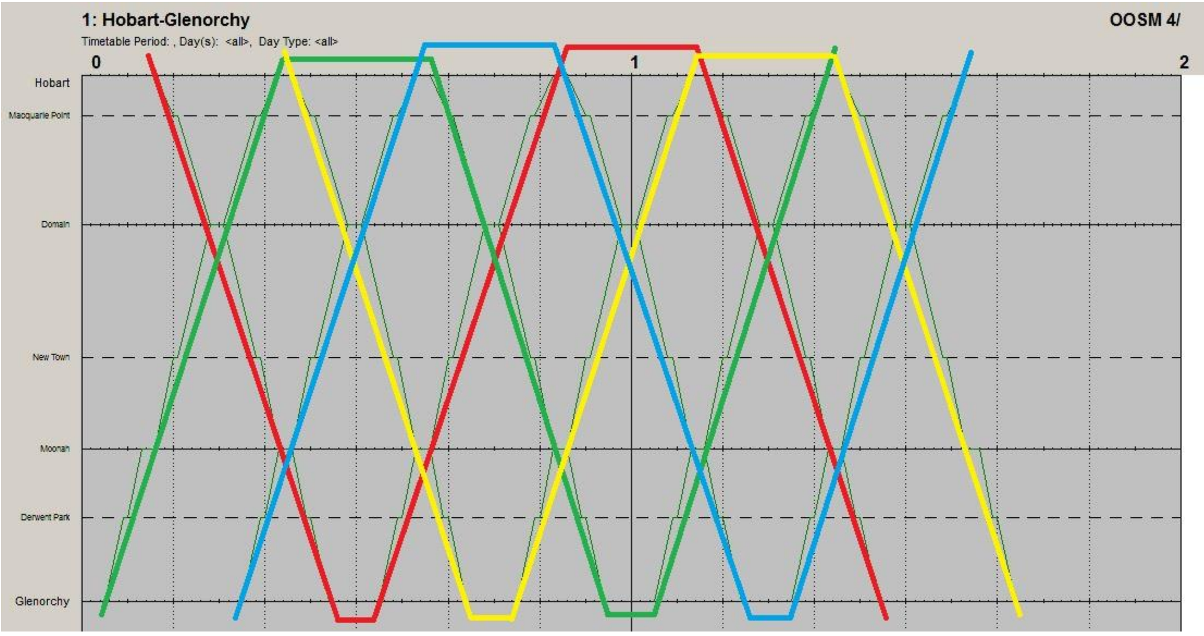
This pattern would require appropriate infrastructure to allow the layover of vehicles at both end termini.

As a general comment, although the addition of stops to the operational pattern (up to 6) increases running time and requires incremental additional equipment, it does not require extensive additional infrastructure in the form of loops.

A general observation is that there seems to be a case for the development of infrastructure at Hobart, Domain, Moonah and Glenorchy as these offer flexibility in all 3 stop to 6 stop scenarios.

Improvements to the headway of services e.g. to 7.5 minute or 10 minute intervals would need to be tested.

Equipment Utilisation:

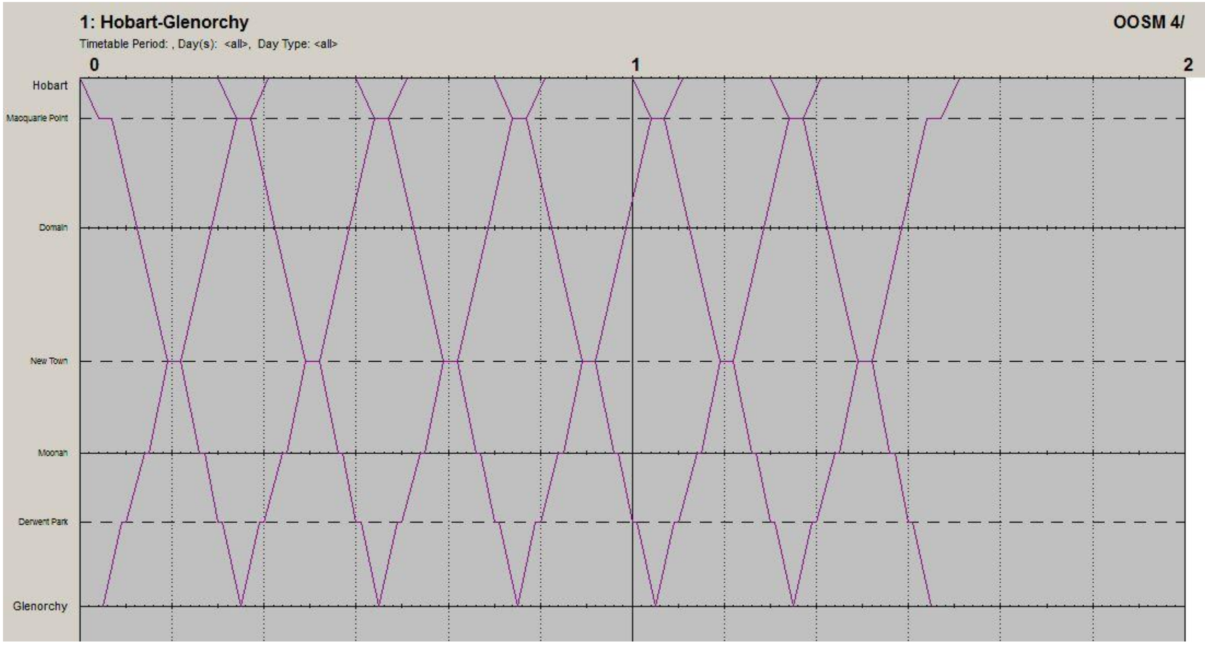


The turnaround times at Glenorchy continue at 5.5 minutes but at Hobart is an unacceptable 1.5 minutes. The time of 1.5 minutes allows little time for an LRV to disembark passengers, reload and for the driver to change ends, as well as provide a buffer for late running.

The diagram for equipment deployment above demonstrates that four vehicles would be required to operate this level of service; however there is a high level of redundancy in case of disruption.

OOSM4: Optimised operational pattern Option 2.

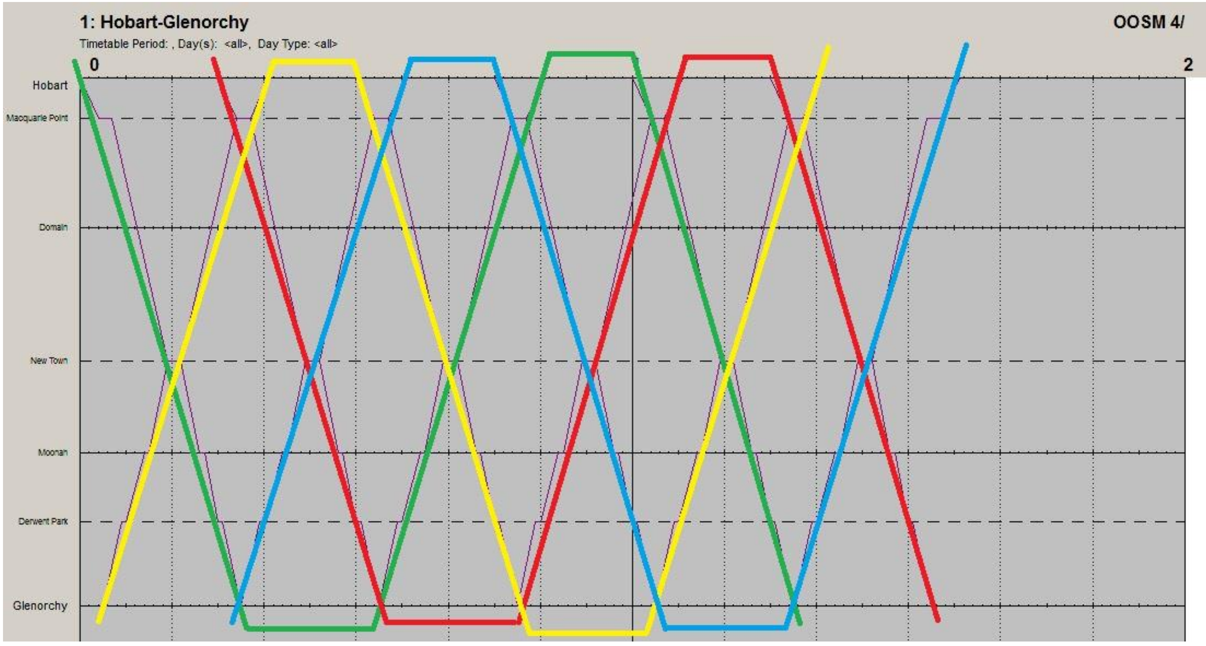
An alternative option bases the infrastructure around the location of stops at Macquarie Point and Newtown. Some consideration was also given to basing the infrastructure around Derwent Park and Domain however this would require some duplication of the on-street route between Elizabeth Street and Macquarie Point to be an effective option.



In this option, at the Glenorchy end there is the likelihood of requiring additional infrastructure to facilitate the arrival and departure of two services in the same time frame. Hence Glenorchy would require at least a two platform layout. This is likely to be accommodated in a layout that provides access to a servicing facility at Glenorchy.

There are generous turnaround times of 9.5 minutes in Hobart and 15 minutes at Glenorchy.

Equipment Utilisation:



This pattern not only has good turnaround times but places loop infrastructure in locations that coincide with passenger stops. This may allow a simple approach when considering improved headways at a future time.

Improved Headways

The headway or frequency of a service is defined as the length of time that elapses between each departure from a given stop. These OOSM timetable models have been predicated on a minimum headway of 15 minutes for a peak operation. Services could be rolled back to 20 minute or 30 minute intervals off-peak (presumably to match the feeder bus services).

In experimenting with headways, one can note the following:

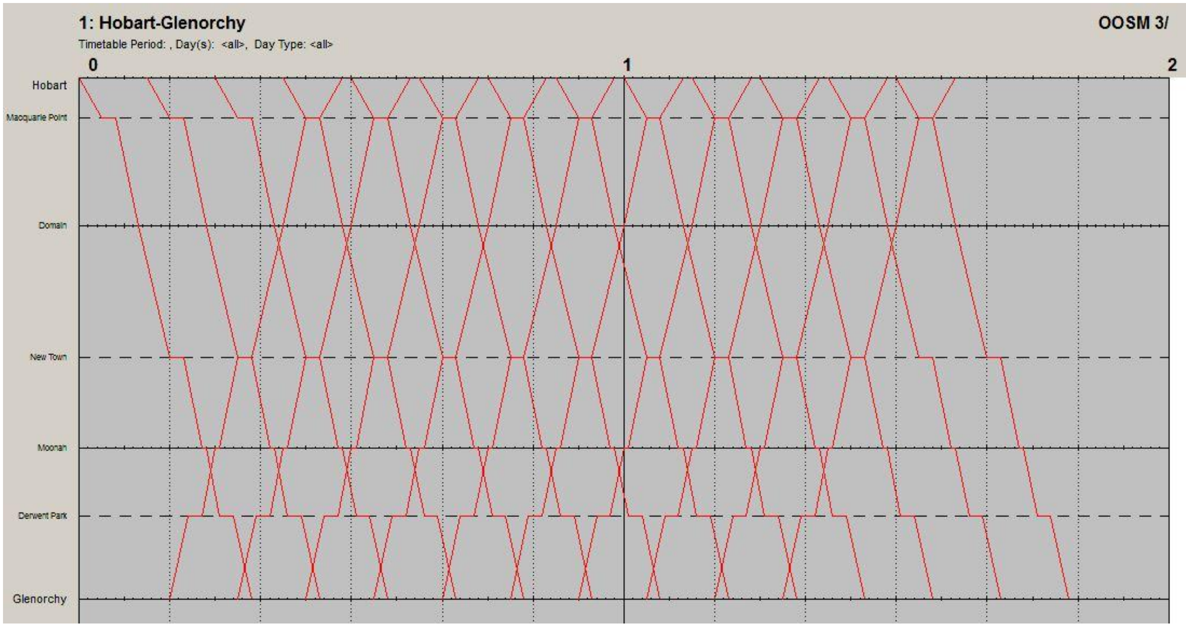
- By observation, a 12 minute headway using all other parameters of OOSM3 as is, with 4 vehicles, could be achieved by having loops at Derwent Park, Newtown and Macquarie Point (but probably modified location). (This has not been tested).

- By observation, a 10 minute headway using all other parameters of OOSM3 as is, with 5 vehicles, could be achieved by having loops at Derwent Park, Newtown and Domain. It may require additional infrastructure (such as a duplicated section) closer to Elizabeth Street. (This has not been tested).

- By observation, a 7.5 minute headway using all other parameters of OOSM3 as is, with 7 vehicles, could be achieved by having loops between Derwent Park and Moonah, Newtown and Macquarie Point (modified location).

Assuming that bus feeder services were to remain at 15 minute intervals in peak periods, but passenger load levels demanded they be staggered to meet different LRT services, the logical approach is to consider a 7.5 minute interval service between Hobart and Glenorchy.

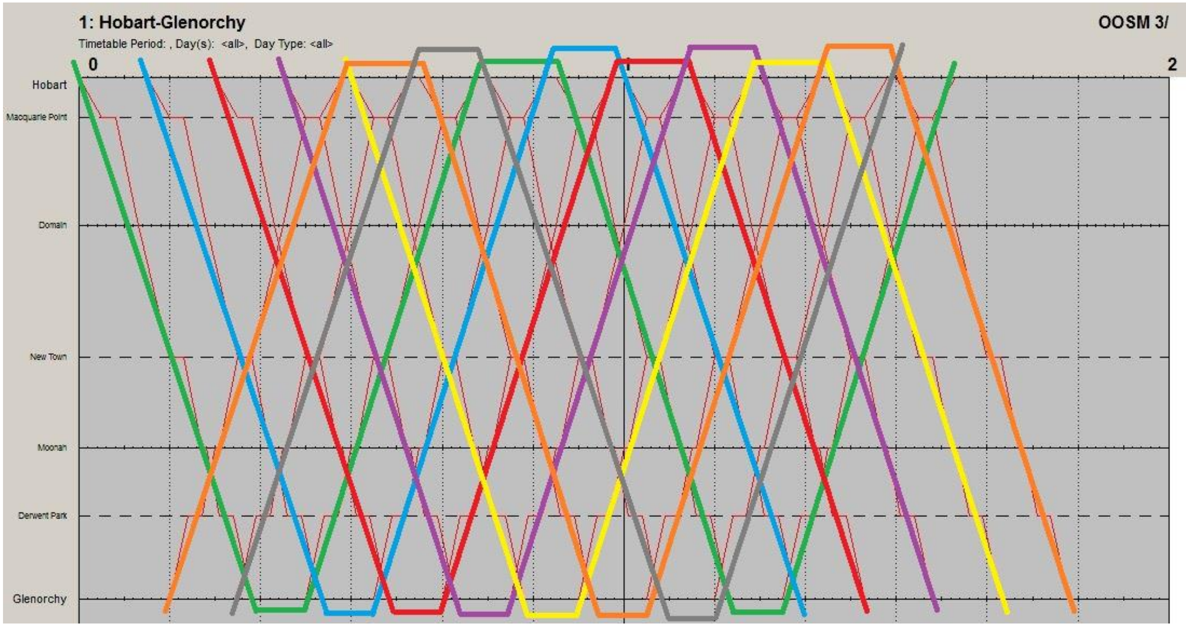
The pattern shown in the diagram below highlights the need for additional infrastructure for a 7.5 minute interval and how this effectively "moves" the infrastructure focus.



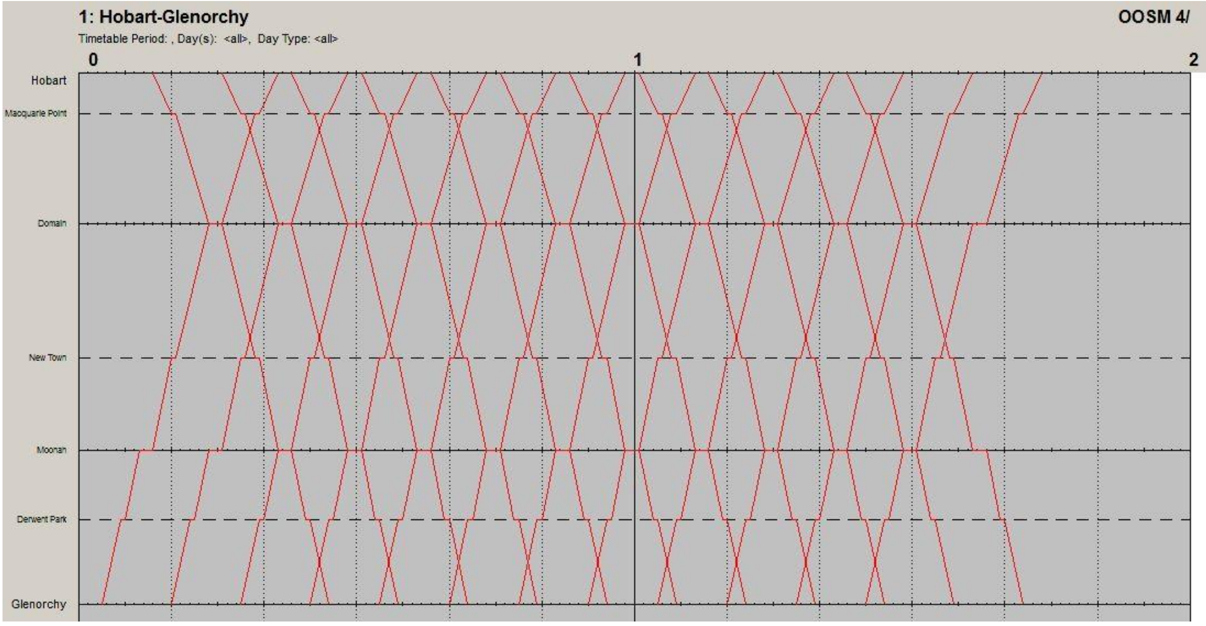
A combination of factors gives rise to the conclusion that this number of stops and consequent running time makes the selection of the location of loop infrastructure a critical issue for the service mix.

Equipment Utilisation:

The diagram below is used to illustrate the need for 7 vehicles to operate a 7.5 minute interval service between Hobart and Glenorchy under OOSM3.

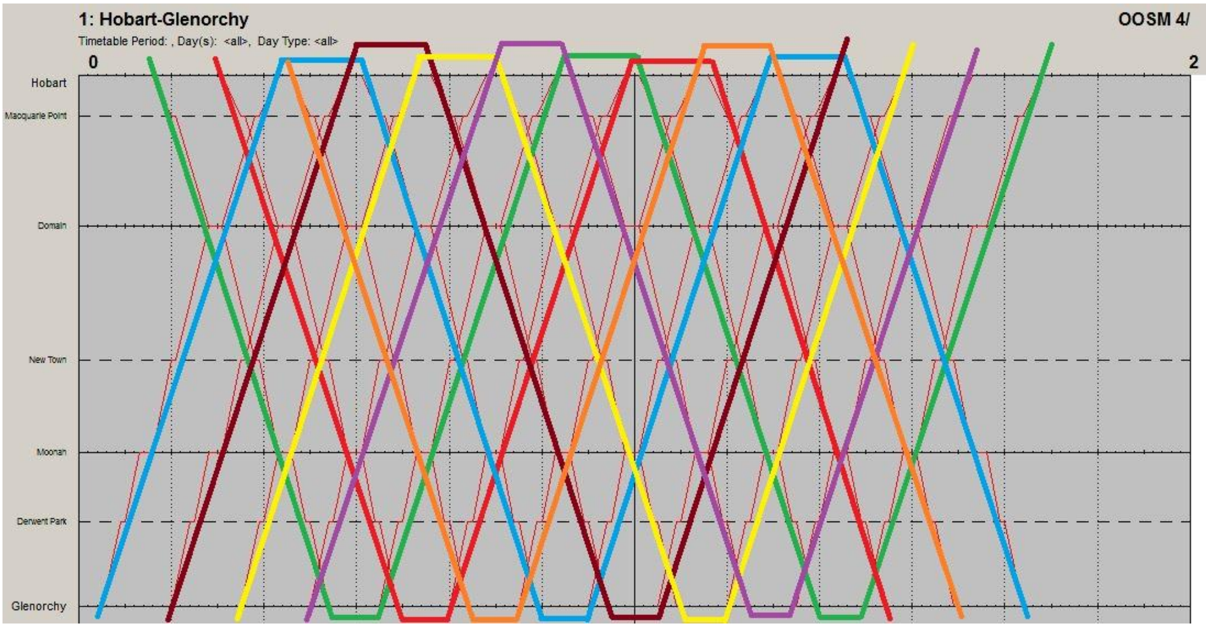


If the same assumptions were applied to the OOSM4 scenario then the following diagrams might be considered in providing a 7.5 minute interval service. This is not optimised but demonstrates the need for crossing loops in the vicinity of Macquarie Point, Domain, Newtown, Moonah and Derwent Park.



Equipment Utilisation:

The diagram below is used to illustrate the need for 7 vehicles to operate a 7.5 minute interval service between Hobart and Glenorchy under OOSM4.



Conclusions

The following summarises the conclusions that can be drawn from the timetable models:

Summary of Equipment and Loop infrastructure requirements:

OOSM	Minimum number of vehicles	Number of loops
OOSM1	3	2
OOSM2	3	2
OOSM3 option 1	3	2
OOSM3 option 2	4	2 (Note 1)
OOSM4 option 1	4	2 (Note 2)
OOSM4 option 2	4	2 (Note 1)

Notes:

For number of vehicles, the size of the vehicle is not defined as no passenger capacity parameters were provided. The number refers to discrete operating entities.

Note 1: Two platforms required at Glenorchy.
Note 2: Two platforms required at Hobart.

General Conclusions

The maximum track speed has relatively little effect on end to end timings, but a reduction in speed restrictions on curves helps to improve overall efficiency in terms of both equipment deployment and operations (e.g. power consumption and braking).
Operational efficiency increases as sectional run time's decrease, especially where run times allow an equipment cycle of two trips per hour. As additional stops are added this efficiency decreases.
Given the assumptions, a more reliable level of service for the given headway of 15 minutes could be achieved by having available a minimum of 4 vehicles in all scenarios.
All scenarios could be operated using two crossing loops, with enhanced terminus infrastructure where required.
Co-locating loops and passenger stops is desirable but some scenarios are less effective at this than others. Consideration of locating crossing loops at non-passenger stops should be made commensurate with long term aims such as additional stopping places, increased frequency and or track duplication.

Plateway

Attachments

Attachment 1 OpenTrack Modelling Assumption Sheet

Project Details		
Client	Hyder	
Project	Hobart Light Rail Study II	
Budget (Quote or Standard)	Quote 11 Dec 2012	
Project Purpose & Outcomes	Create Optimal Operating Service Models OOSM1	
Run Times Required	Best (Shortest) Possible ☒	Typical Average Achievable ☒
Route	Hobart to Glenorchy	
Date of TSRs		
New Consists Required?	No ☒ Yes ☐	

Train Driving Style: These assumptions will be set depending if you have previously selected ***Best*** (fastest) or ***Typical*** driving style. If you want to further amend them please indicate below:				
Options	**Typical** ☒	**Best** ☐	**Amend**	***Other Value***
Max. Tractive Effort	95%	100%	☐	
Braking Method	Dynamic	Air/Dynamic	☐	
Braking Rates	Flexity: -0.6m/s^2		☐	
Other Handling Assumptions	Normal	Aggressive	☐	

Unless specified otherwise the model will be run with the following default assumptions. Please show any amendments you require.

Train Characteristics - Technical		**Amend**	***Amended Value***
Resistance Factor (Strahl Formula)	3.2999 (for both Flexity & DMU)	☐	
Rotating Mass	1.0599 (for both Flexity & DMU)	☐	

Courses		**Amend**	***Amended Value***
Timetable Version	N/A (single LRV only)	☐	
Stop Dwells	Flexity tram: 30 seconds	☐	
Staff/TOW Stops?	LRV stops at staff change zero dwell	☐	
Loops	LRVs run on main line, except where stopping in loops as listed.	☐	

Signalling & Safeworking	**Amend**	***Amended Value***

Safeworking System	N/A (single LRV only)	☐	
Default Signal Sighting Distance	5,000m	☐	
Train Operation Rules	N/A (single LRV only)	☐	
Priority Rules (if any)	LRV (single consist)	☐	
Road Reservation (Sections)	Assumed LRT priority	☐	
Speed Board Treatment	End of LRV clears speed board before accelerating.	☐	

Delays		**Amend**	***Amended Value***
TSRs	None	☐	
Other Track Delays	None	☐	
Rollingstock Delays	None	☐	
Departure Delays	None	☐	

Plateway

Attachment 2 SRT Comparison of Infrastructure Constraints

Summary

	It 0	It 1	It 2	It 3	It 3a
Outbound	805	873	855	842	768
Inbound	801	866	847	836	762

Iterations – SRT for each change

		It 0	Secs			It 1	Secs		
HOBART	Dep.	0:00:00	0	0:00:00	0	0:00:00	0	0:00:00	0
NEWTOWN	Arr.	0:06:40	400	0:06:40	400	0:07:39	459	0:07:39	459
NEWTOWN	Dep.	0:07:10	430	0:00:30	30	0:08:09	489	0:00:30	30
MOONAH	Arr.	0:09:06	546	0:01:56	116	0:10:09	609	0:02:00	120
MOONAH	Dep.	0:09:36	576	0:00:30	30	0:10:39	639	0:00:30	30
DERWENT	Arr.	0:11:08	668	0:01:32	92	0:12:13	733	0:01:34	94
DERWENT	Dep.	0:11:38	698	0:00:30	30	0:12:43	763	0:00:30	30
GLENORCHY	Arr.	0:13:25	805	0:01:47	107	0:14:33	873	0:01:50	110
GLENORCHY	Dep.	0:30:00	1800	0:00:00	0	0:30:00	1800	0:00:00	0
DERWENT	Arr.	0:31:47	1907	0:01:47	107	0:31:50	1910	0:01:50	110
DERWENT	Dep.	0:32:17	1937	0:00:30	30	0:32:20	1940	0:00:30	30
MOONAH	Arr.	0:33:49	2029	0:01:32	92	0:33:54	2034	0:01:34	94
MOONAH	Dep.	0:34:19	2059	0:00:30	30	0:34:24	2064	0:00:30	30
NEWTOWN	Arr.	0:36:15	2175	0:01:56	116	0:36:23	2183	0:01:59	119
NEWTOWN	Dep.	0:36:45	2205	0:00:30	30	0:36:53	2213	0:00:30	30
HOBART	Arr.	0:43:21	2601	0:06:36	396	0:44:26	2666	0:07:33	453

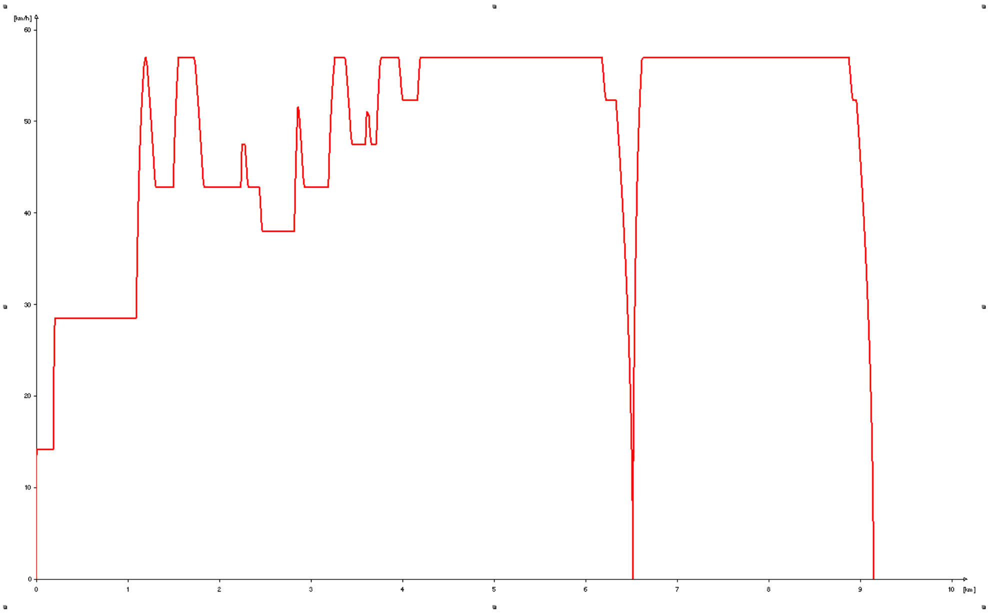
		It 2	Secs			It 3	Secs		
HOBART	Dep.	0:00:00	0	0:00:00	0	0:00:00	0	0:00:00	0
NEWTOWN	Arr.	0:07:35	455	0:07:35	455	0:07:33	453	0:07:33	453
NEWTOWN	Dep.	0:08:05	485	0:00:30	30	0:08:03	483	0:00:30	30
MOONAH	Arr.	0:10:00	600	0:01:55	115	0:09:53	593	0:01:50	110
MOONAH	Dep.	0:10:30	630	0:00:30	30	0:10:23	623	0:00:30	30
DERWENT	Arr.	0:12:00	720	0:01:30	90	0:11:50	710	0:01:27	87
DERWENT	Dep.	0:12:30	750	0:00:30	30	0:12:20	740	0:00:30	30
GLENORCHY	Arr.	0:14:15	855	0:01:45	105	0:14:02	842	0:01:42	102
GLENORCHY	Dep.	0:30:00	1800	0:00:00	0	0:30:00	1800	0:00:00	0
DERWENT	Arr.	0:31:45	1905	0:01:45	105	0:31:42	1902	0:01:42	102
DERWENT	Dep.	0:32:15	1935	0:00:30	30	0:32:12	1932	0:00:30	30
MOONAH	Arr.	0:33:45	2025	0:01:30	90	0:33:39	2019	0:01:27	87

MOONAH	Dep.	0:34:15	2055	0:00:30	30	0:34:09	2049	0:00:30	30
NEWTOWN	Arr.	0:36:09	2169	0:01:54	114	0:35:59	2159	0:01:50	110
NEWTOWN	Dep.	0:36:39	2199	0:00:30	30	0:36:29	2189	0:00:30	30
HOBART	Arr.	0:44:07	2647	0:07:28	448	0:43:56	2636	0:07:27	447

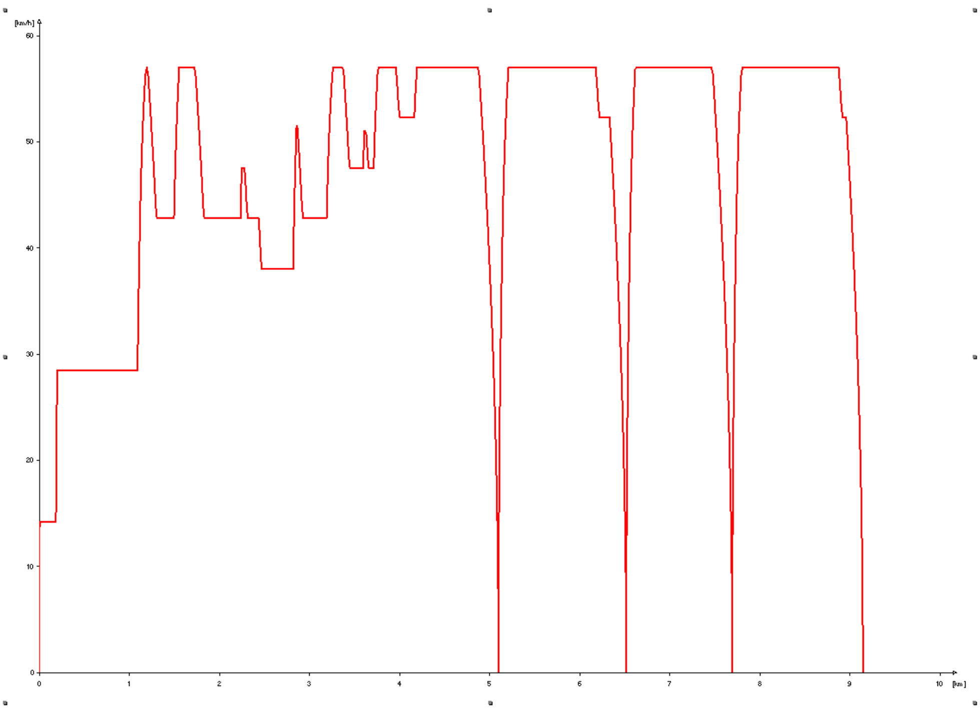
		It 3a	Secs		
HOBART	Dep.	0:00:00	0	0:00:00	0
NEWTOWN	Arr.	0:06:22	382	0:06:22	382
NEWTOWN	Dep.	0:06:52	412	0:00:30	30
MOONAH	Arr.	0:08:41	521	0:01:49	109
MOONAH	Dep.	0:09:11	551	0:00:30	30
DERWENT	Arr.	0:10:38	638	0:01:27	87
DERWENT	Dep.	0:11:08	668	0:00:30	30
GLENORCHY	Arr.	0:12:48	768	0:01:40	100
GLENORCHY	Dep.	0:30:00	1800	0:00:00	0
DERWENT	Arr.	0:31:40	1900	0:01:40	100
DERWENT	Dep.	0:32:10	1930	0:00:30	30
MOONAH	Arr.	0:33:37	2017	0:01:27	87
MOONAH	Dep.	0:34:07	2047	0:00:30	30
NEWTOWN	Arr.	0:35:55	2155	0:01:48	108
NEWTOWN	Dep.	0:36:25	2185	0:00:30	30
HOBART	Arr.	0:42:42	2562	0:06:17	377

Attachment 3 OpenTrack Outputs

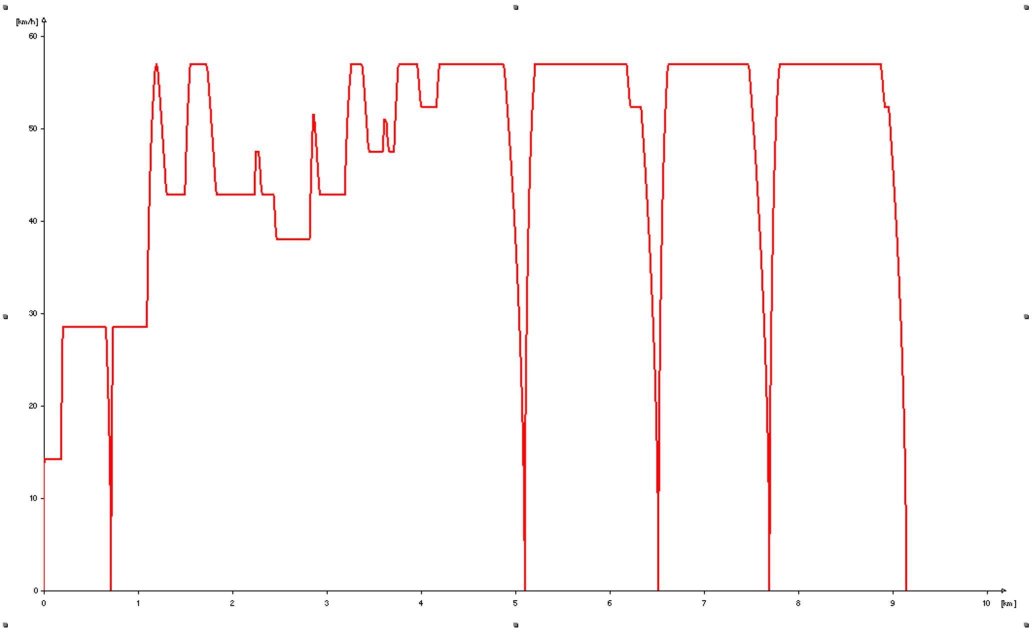
Speed distance plot for OOSM1



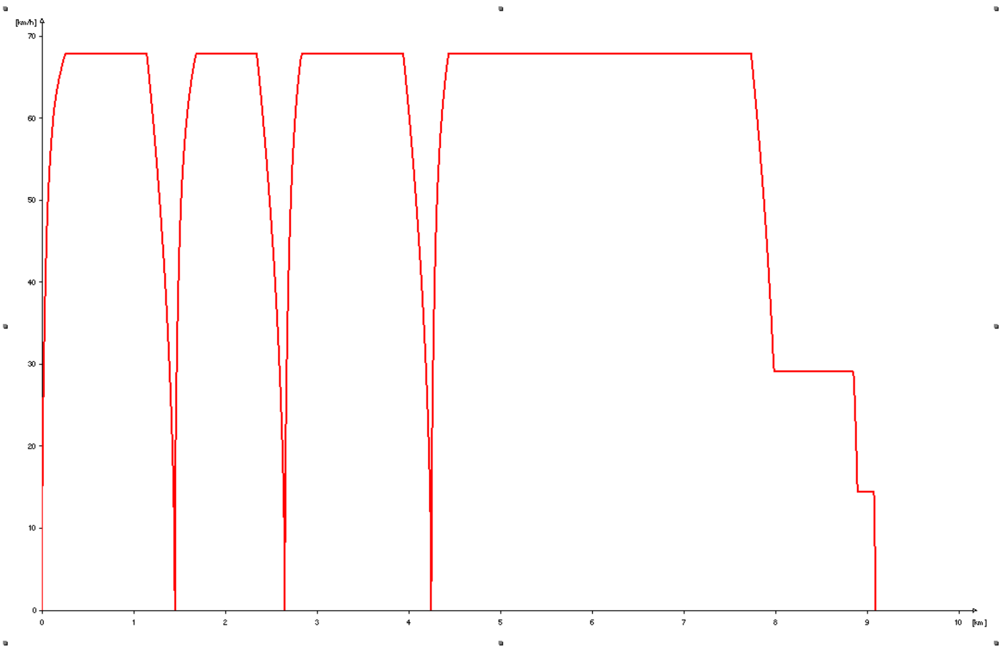
Speed distance plot for OOSM3



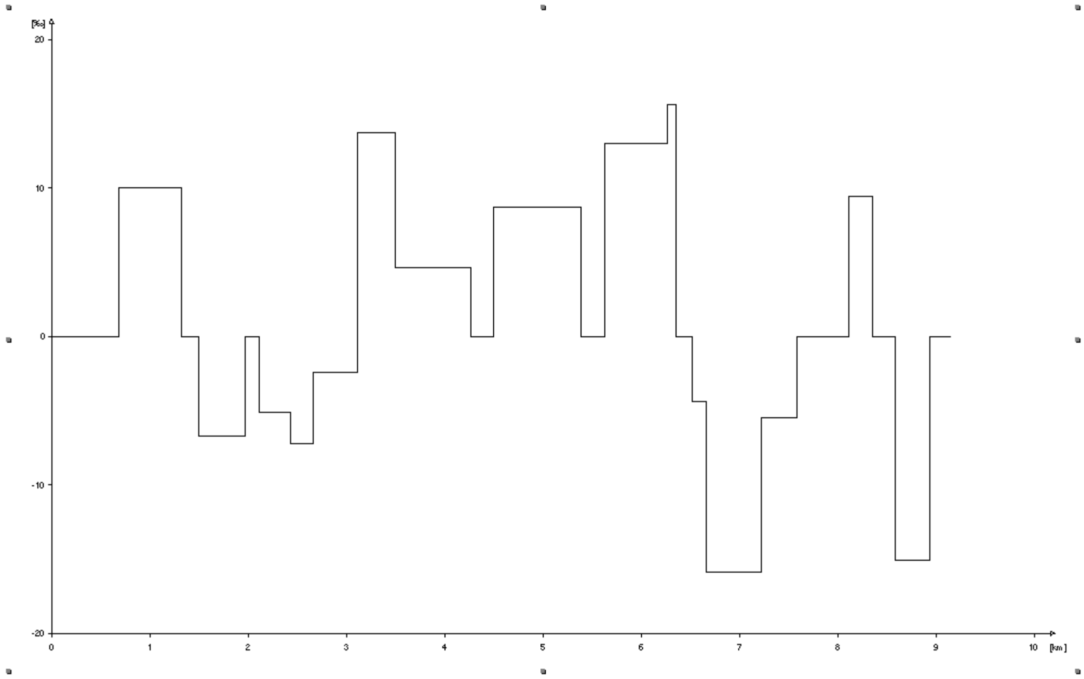
Speed distance plot for OOSM4



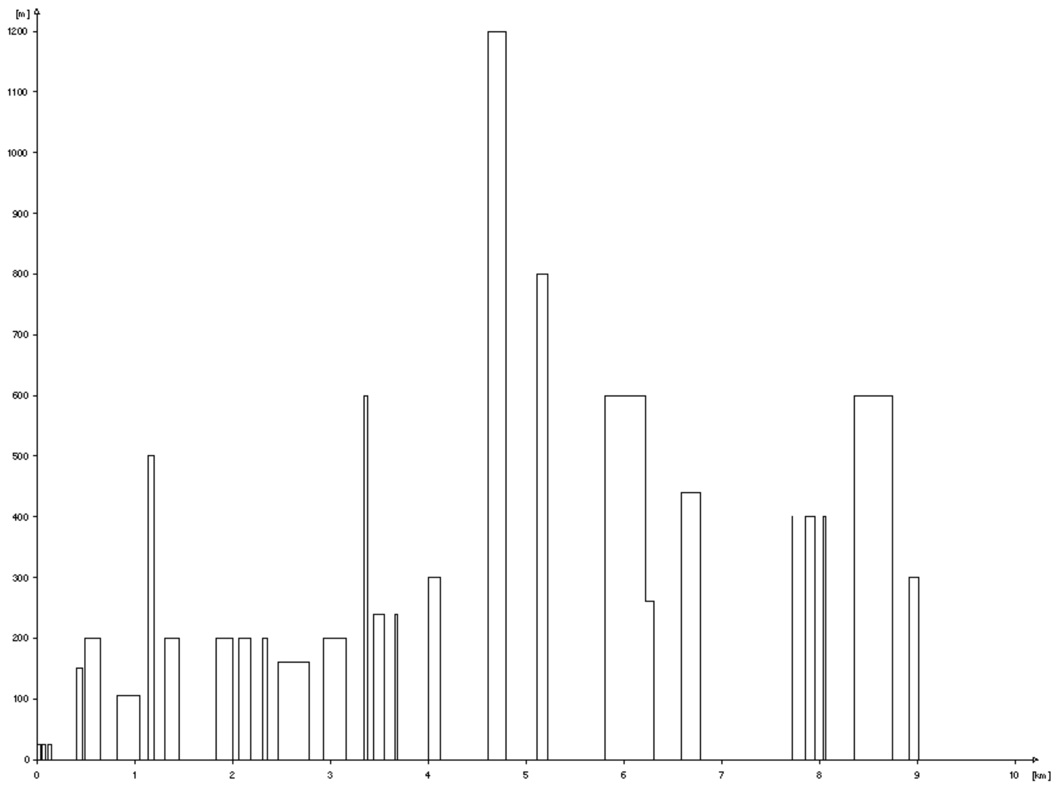
Speed distance plot where curve restrictions have been removed and line speed is 70 kph. Note that the vehicle performs to the maximum of its ability over the entire line under this scenario.



Gradient plot



Radius of curves plot



APPENDIX B – CAPEX COST DATA

Hobart Light Rail

OHW and Electrical Units Rolling Stock - OOSM Comparison Summary

OOSM	Total CAPEX cost (2011)	Plus 5% cost increase since 2011
1 - Narrow Gauge	$ 67,876,000.00	**$ 71,270,000.00**
1 - Standard Gauge	$ 66,857,000.00	**$ 70,200,000.00**
2 - Narrow Gauge	$ 68,231,000.00	**$ 71,643,000.00**
2 - Standard Gauge	$ 67,211,000.00	**$ 70,572,000.00**
3 - Narrow Gauge	$ 68,583,000.00	**$ 72,012,000.00**
3 - Standard Gauge	$ 67,565,000.00	**$ 70,943,000.00**
4 - Narrow Gauge	$ 75,917,000.00	**$ 79,713,000.00**
4 - Standard Gauge	$ 74,263,000.00	**$ 77,976,000.00**

Hobart Light Rail

OHW and Electrical Units Rolling Stock - OOSM 01 - Narrow Gauge

Glenorchy to Elizabeth Street (Franklin Square)						
		Qty	Unit	Rate	Subtotal	Total
Track - Glenorchy to Mawson Place						**$ 30,344,800.00**
Clearing / Stripping	Formation stripping and grubbing, 5.4m width.	46,440	m²	$ 5.00	$ 232,200.00	
Remove existing rail and sleepers and stockpile	Remove existing track	8,600	m	$ 85.00	$ 731,000.00	
Subgrade improvement - replace unsuitable with imported, disposa of excavated material and geotextile to base	Allowance for 100% subgrade improvement, 4.4m minimum width. Excavation to be minimised with areas of good formation being rolled, compacted to form subgrade	37,840	m²	$ 95.00	$ 3,594,800.00	
Capping Layer	Install new capping layer. 4.4m width throughout.	37,840	m²	$ 20.00	$ 756,800.00	
Drainage	Allowance for drainage channels & cross drains	1,000	m	$ 350.00	$ 350,000.00	
Re establish swale drains	Swale drain either side of formation	8,600	m	$ 60.00	$ 516,000.00	
Subsoil drains along alignment	Assume requirement for 30% subsoil drains	2,580	m	$ 60.00	$ 154,800.00	
Subgrade preparation	Prepare subgrade. 4.4m width throughout.	37,840	m²	$ 5.00	$ 189,200.00	
Supply and install passing loop turnouts	1 x passing loop (2 turnouts) plus Terminus platforms	4	no	$ 250,000.00	$ 1,000,000.00	
Lay new sleepers	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 275.00	$ 2,475,000.00	
Lay existing or supplied rail	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 230.00	$ 2,070,000.00	
Rail grinding	Assume profiling required to match rail to LRV wheel profile, optimised for higher speed operation	9,000	m	$ 60.00	$ 540,000.00	
Ballast replacement	New Ballast throughout. Assumes 2.82t per m	9,000	m	$ 150.00	$ 1,350,000.00	
Track tamping	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 25.00	$ 225,000.00	
OHW Traction System - Electrification of the line	8.6km route length plus passing loop (200m) and terminus platforms, substation.	1	Item	$ 9,750,000.00	$ 9,750,000.00	
Signalling - Electronic Interlocking System	8.6km route length plus passing loop (200m) and terminus platforms.	1	Item	$ 4,150,000.00	$ 4,150,000.00	
Level crossing upgrades	Resurfacing, drainage, upgrade of lights, booms, bells where required.	11	ea	$ 190,000.00	$ 2,090,000.00	
Service proofing		1	ea	$ 170,000.00	$ 170,000.00	
Track (Additional) - Mawson Place to Elizabeth St (Franklin Square)						**$ 1,738,500.00**
Initial Road Works	Remove existing Pavement, kerb stones, etc	200	m	$ 750.00	$ 150,000.00	
Single Track - Rail, Sleeper, Concrete to rail level	200m extension length	200	m	$ 1,300.00	$ 260,000.00	
Curved track (<30m Radius) Additional Cost	Additional set out, reinforcement, rail bending, etc	39	m	$ 1,500.00	$ 58,500.00	
Install OHLE	Foundation, Poles, Suspension, Curve Detailing, Cables & Return	200	m	$ 1,500.00	$ 300,000.00	
Traffic Management	Through construction period, diversions, road closure, etc	1	ea	$ 200,000.00	$ 200,000.00	
Tram / Pedestrian / Traffic interface works	Install new bollards, warning notices, line marking	200	m	$ 400.00	$ 80,000.00	
Intersection modification (Davey St x2)	Changes to signal priorities, removal of some turn functions, new signage	2	ea	$ 250,000.00	$ 500,000.00	
Service Proofing	200m extension length	200	m	$ 450.00	$ 90,000.00	
Urban Design & Landscaping	Allowance for pavement redesign, integration of light rail into streetscape, etc.	1	ea	$ 100,000.00	$ 100,000.00	
Structure						**$ 3,100,000.00**
Light rail depot	Including shed, stabling road, turnout to mainline	1	Item	$ 3,100,000.00	$ 3,100,000.00	
Stops						**$ 2,901,300.00**
Stops (Moonah and Glenorchy)	Minimal platform structure, shelters, etc	2	ea	$ 150,000.00	$ 300,000.00	
Elizabeth Street terminus	Centrepiece station, integration to existing streetscape	1	ea	$ 400,000.00	$ 400,000.00	
Pathways / ramps	Approach ramps at end of platform - 30m per stn	90	m	$ 320.00	$ 28,800.00	
Pedestrian crossings	Basic passive cribs - 1 per station (not CBD stop)	2	ea	$ 10,000.00	$ 20,000.00	
Power to stops	Connection for Information displays, lighting	3	Item	$ 100,000.00	$ 300,000.00	
Bus interchange and park & ride facilities	Glenorchy and Moonah bus developments	1	Item	$ 1,800,000.00	$ 1,800,000.00	
Drainage	Drainage from platform to existing sewer or rail drainage	150	m	$ 350.00	$ 52,500.00	
Urban design / landscaping / bush care		**0.5%**	**Item**	**$ 38,084,600.00**	**$ 190,423.00**	**$ 190,423**
Total Contractor's Costs						**$ 38,275,000**
Client Costs						
Project management & project controls				5.0%		$ 1,913,800
Design				4.5%		$ 1,722,400
Other Costs						
Rolling stock - New electrically powered units		3	ea	$ 5,720,000.00		$ 17,160,000
Subtotal						**$ 59,071,000**
Contingency		12%				$ 7,089,000
Rolling Stock Contingency (New Units)		10%				$ 1,716,000
Total CAPEX Cost (2011 Rates)						**$ 67,876,000**
Plus Cost Increase Since 2011 Allowance		5%				**$ 71,270,000**

Hobart Light Rail

OHW and Electrical Units Rolling Stock - OOSM 01 - Standard Gauge with Dual Gauge Provision

Glenorchy to Elizabeth Street (Franklin Square)						
		Qty	**Unit**	**Rate**	**Subtotal**	**Total**
Track - Glenorchy to Mawson Place						**$ 31,062,300.00**
Clearing / Stripping	Formation stripping and grubbing, 5.9m width.	50,740	m²	$ 5.00	$ 253,700.00	
Remove existing rail and sleepers and stockpile	Remove existing track	8,600	m	$ 85.00	$ 731,000.00	
Subgrade improvement - replace unsuitable with imported, disposal of excavated material and geotextile to base	Allowance for 100% subgrade improvement, 4.9m minimum width. Excavation to be minimised with areas of good formation being rolled, compacted to form subgrade	42,140	m²	$ 95.00	$ 4,003,300.00	
Capping Layer	Install new capping layer. 4.9m width throughout.	42,140	m²	$ 20.00	$ 842,800.00	
Drainage	Allowance for drainage channels & cross drains	1,000	m	$ 350.00	$ 350,000.00	
Re establish swale drains	Swale drain either side of formation	8,600	m	$ 60.00	$ 516,000.00	
Subsoil drains along alignment	Assume requirement for 30% subsoil drains	2,580	m	$ 60.00	$ 154,800.00	
Subgrade preparation	Prepare subgrade. 4.9m width throughout.	42,140	m²	$ 5.00	$ 210,700.00	
Supply and install passing loop turnouts	1 x passing loop (2 turnouts) plus Terminus platforms	4	no	$ 250,000.00	$ 1,000,000.00	
Lay new sleepers	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 275.00	$ 2,475,000.00	
Lay existing or supplied rail	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 230.00	$ 2,070,000.00	
Rail grinding	Assume profiling required to match rail to LRV wheel profile, optimised for higher speed operation	9,000	m	$ 60.00	$ 540,000.00	
Ballast replacement	New Ballast throughout. Assumes 3.18t per m	9,000	m	$ 170.00	$ 1,530,000.00	
Track tamping	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 25.00	$ 225,000.00	
OHW Traction System - Electrification of the line	8.6km route length plus passing loop (200m) and terminus platforms, substation.	1	Item	$ 9,750,000.00	$ 9,750,000.00	
Signalling - Electronic Interlocking System	8.6km route length plus passing loop (200m) and terminus platforms.	1	Item	$ 4,150,000.00	$ 4,150,000.00	
Level crossing upgrades	Resurfacing, drainage, upgrade of lights, booms, bells where required.	11	ea	$ 190,000.00	$ 2,090,000.00	
Service proofing		1	ea	$ 170,000.00	$ 170,000.00	
Track (Additional) - Mawson Place to Elizabeth St (Franklin Square)						**$ 1,738,500.00**
Initial Road Works	Remove existing Pavement, kerb stones, etc	200	m	$ 750.00	$ 150,000.00	
Single Track - Rail, Sleeper, Concrete to rail level	200m extension length	200	m	$ 1,300.00	$ 260,000.00	
Curved track (<30m Radius) Additional Cost	Additional set out, reinforcement, rail bending, etc	39	m	$ 1,500.00	$ 58,500.00	
Install OHLE	Foundation, Poles, Suspension, Curve Detailing, Cables & Return	200	m	$ 1,500.00	$ 300,000.00	
Traffic Management	Through construction period, diversions, road closure, etc	1	ea	$ 200,000.00	$ 200,000.00	
Tram / Pedestrian / Traffic interface works	Install new bollards, warning notices, line marking	200	m	$ 400.00	$ 80,000.00	
Intersection modification (Davey St x2)	Changes to signal priorities, removal of some turn functions, new signage	2	ea	$ 250,000.00	$ 500,000.00	
Service Proofing	200m extension length	200	m	$ 450.00	$ 90,000.00	
Urban Design & Landscaping	Allowance for pavement redesign, integration of light rail into streetscape, etc.	1	ea	$ 100,000.00	$ 100,000.00	
Structure						**$ 3,100,000.00**
Light rail depot	Including shed, stabling road, turnout to mainline	1	Item	$ 3,100,000.00	$ 3,100,000.00	
Stops						**$ 2,901,300.00**
Stops (Moonah and Glenorchy)	Minimal platform structure, shelters, etc	2	ea	$ 150,000.00	$ 300,000.00	
Elizabeth Street terminus	Centrepiece station, integration to existing streetscape	1	ea	$ 400,000.00	$ 400,000.00	
Pathways / ramps	Approach ramps at end of platform - 30m per stn	90	m	$ 320.00	$ 28,800.00	
Pedestrian crossings	Basic passive cribs - 1 per station (not CBD stop)	2	ea	$ 10,000.00	$ 20,000.00	
Power to stops	Connection for Information displays, lighting	3	Item	$ 100,000.00	$ 300,000.00	
Bus interchange and park & ride facilities	Glenorchy and Moonah bus developments	1	Item	$ 1,800,000.00	$ 1,800,000.00	
Drainage	Drainage from platform to existing sewer or rail drainage	150	m	$ 350.00	$ 52,500.00	
Urban design / landscaping / bush care		**0.5%**	**Item**	**$ 38,802,100.00**	**$ 194,010.50**	**$ 194,011**
Total Contractor's Costs						**$ 38,996,000**
Client Costs						
Project management & project controls				5%		$ 1,949,800
Design				4.5%		$ 1,754,900
Other Costs						
Rolling stock - New electrically powered units		3	ea	$ 5,200,000.00		$ 15,600,000
Subtotal						**$ 58,301,000**
Contingency		12%				$ 6,996,000
Rolling Stock Contingency (New Units)		10%				$ 1,560,000
Total CAPEX Cost (2011 Rates)						**$ 66,857,000**
Plus Cost Increase Since 2011 Allowance		5%				**$ 70,200,000**

Hobart Light Rail

OHW and Electrical Units Rolling Stock - OOSM 02 - Narrow Gauge

Glenorchy to Elizabeth Street (Franklin Square)						
		Qty	Unit	Rate	Subtotal	Total
Track - Glenorchy to Mawson Place						$ 30,344,800.00
Clearing / Stripping	Formation stripping and grubbing, 5.4m width.	46,440	m²	$ 5.00	$ 232,200.00	
Remove existing rail and sleepers and stockpile	Remove existing track	8,600	m	$ 85.00	$ 731,000.00	
Subgrade improvement - replace unsuitable with imported, disposa of excavated material and geotextile to base	Allowance for 100% subgrade improvement, 4.4m minimum width. Excavation to be minimised with areas of good formation being rolled, compacted to form subgrade	37,840	m²	$ 95.00	$ 3,594,800.00	
Capping Layer	Install new capping layer. 4.4m width throughout.	37,840	m²	$ 20.00	$ 756,800.00	
Drainage	Allowance for drainage channels & cross drains	1,000	m	$ 350.00	$ 350,000.00	
Re establish swale drains	Swale drain either side of formation	8,600	m	$ 60.00	$ 516,000.00	
Subsoil drains along alignment	Assume requirement for 30% subsoil drains	2,580	m	$ 60.00	$ 154,800.00	
Subgrade preparation	Prepare subgrade. 4.4m width throughout.	37,840	m²	$ 5.00	$ 189,200.00	
Supply and install passing loop turnouts	1 x passing loop (2 turnouts) plus Terminus platforms	4	no	$ 250,000.00	$ 1,000,000.00	
Lay new sleepers	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 275.00	$ 2,475,000.00	
Lay existing or supplied rail	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 230.00	$ 2,070,000.00	
Rail grinding	Assume profiling required to match rail to LRV wheel profile, optimised for higher speed operation	9,000	m	$ 60.00	$ 540,000.00	
Ballast replacement	New Ballast throughout. Assumes 2.82t per m	9,000	m	$ 150.00	$ 1,350,000.00	
Track tamping	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 25.00	$ 225,000.00	
OHW Traction System - Electrification of the line	8.6km route length plus passing loop (200m) and terminus platforms, substation.	1	Item	$ 9,750,000.00	$ 9,750,000.00	
Signalling - Electronic Interlocking System	8.6km route length plus passing loop (200m) and terminus platforms.	1	Item	$ 4,150,000.00	$ 4,150,000.00	
Level crossing upgrades	Resurfacing, drainage, upgrade of lights, booms, bells where required.	11	ea	$ 190,000.00	$ 2,090,000.00	
Service proofing		1	ea	$ 170,000.00	$ 170,000.00	
Track (Additional) - Mawson Place to Elizabeth St (Franklin Square)						$ 1,738,500.00
Initial Road Works	Remove existing Pavement, kerb stones, etc	200	m	$ 750.00	$ 150,000.00	
Single Track - Rail, Sleeper, Concrete to rail level	200m extension length	200	m	$ 1,300.00	$ 260,000.00	
Curved track (<30m Radius) Additional Cost	Additional set out, reinforcement, rail bending, etc	39	m	$ 1,500.00	$ 58,500.00	
Install OHLE	Foundation, Poles, Suspension, Curve Detailing, Cables & Return	200	m	$ 1,500.00	$ 300,000.00	
Traffic Management	Through construction period, diversions, road closure, etc	1	ea	$ 200,000.00	$ 200,000.00	
Tram / Pedestrian / Traffic interface works	Install new bollards, warning notices, line marking	200	m	$ 400.00	$ 80,000.00	
Intersection modification (Davey St x2)	Changes to signal priorities, removal of some turn functions, new signage	2	ea	$ 250,000.00	$ 500,000.00	
Service Proofing	200m extension length	200	m	$ 450.00	$ 90,000.00	
Urban Design & Landscaping	Allowance for pavement redesign, integration of light rail into streetscape, etc.	1	ea	$ 100,000.00	$ 100,000.00	
Structure						$ 3,100,000.00
Light rail depot	Including shed, stabling road, turnout to mainline	1	Item	$ 3,100,000.00	$ 3,100,000.00	
Stops						$ 3,188,400.00
Stops (Moonah, Derwent Park and Glenorchy)	Minimal platform structure, shelters, etc	3	ea	$ 150,000.00	$ 450,000.00	
Elizabeth Street terminus	Centrepiece station, integration to existing streetscape	1	ea	$ 400,000.00	$ 400,000.00	
Pathways / ramps	Approach ramps at end of platform - 30m per stn	120	m	$ 320.00	$ 38,400.00	
Pedestrian crossings	Basic passive cribs -1 per station (not CBD stop)	3	ea	$ 10,000.00	$ 30,000.00	
Power to stops	Connection for Information displays, lighting	4	Item	$ 100,000.00	$ 400,000.00	
Bus interchange and park & ride facilities	Glenorchy and Moonah bus developments	1	Item	$ 1,800,000.00	$ 1,800,000.00	
Drainage	Drainage from platform to existing sewer or rail drainage	200	m	$ 350.00	$ 70,000.00	
Urban design / landscaping / bush care		**0.5%**	**Item**	**$ 38,371,700.00**	**$ 191,858.50**	**$ 191,859**
Total Contractor's Costs						**$ 38,564,000**
Client Costs						
Project management & project controls				5.0%		$ 1,928,200
Design				4.5%		$ 1,735,400
Other Costs						
Rolling stock - New electrically powered units		3	ea	$ 5,720,000.00		$ 17,160,000
Subtotal						**$ 59,388,000**
Contingency		12%				$ 7,127,000
Rolling Stock Contingency (New Units)		10%				$ 1,716,000
Total CAPEX Cost (2011 Rates)						**$ 68,231,000**
Plus Cost Increase Since 2011 Allowance		5%				**$ 71,643,000**

Hobart Light Rail

OHW and Electrical Units Rolling Stock - OOSM 02 - Standard Gauge with Dual Gauge Provision

Glenorchy to Elizabeth Street (Franklin Square)						
		Qty	Unit	Rate	Subtotal	Total
Track - Glenorchy to Mawson Place						$ 31,062,300.00
Clearing / Stripping	Formation stripping and grubbing, 5.9m width.	50,740	m²	$ 5.00	$ 253,700.00	
Remove existing rail and sleepers and stockpile	Remove existing track	8,600	m	$ 85.00	$ 731,000.00	
Subgrade improvement - replace unsuitable with imported, disposal of excavated material and geotextile to base	Allowance for 100% subgrade improvement, 4.9m minimum width. Excavation to be minimised with areas of good formation being rolled, compacted to form subgrade	42,140	m²	$ 95.00	$ 4,003,300.00	
Capping Layer	Install new capping layer. 4.9m width throughout.	42,140	m²	$ 20.00	$ 842,800.00	
Drainage	Allowance for drainage channels & cross drains	1,000	m	$ 350.00	$ 350,000.00	
Re establish swale drains	Swale drain either side of formation	8,600	m	$ 60.00	$ 516,000.00	
Subsoil drains along alignment	Assume requirement for 30% subsoil drains	2,580	m	$ 60.00	$ 154,800.00	
Subgrade preparation	Prepare subgrade. 4.9m width throughout.	42,140	m²	$ 5.00	$ 210,700.00	
Supply and install passing loop turnouts	1 x passing loop (2 turnouts) plus Terminus platforms	4	no	$ 250,000.00	$ 1,000,000.00	
Lay new sleepers	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 275.00	$ 2,475,000.00	
Lay existing or supplied rail	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 230.00	$ 2,070,000.00	
Rail grinding	Assume profiling required to match rail to LRV wheel profile, optimised for higher speed operation	9,000	m	$ 60.00	$ 540,000.00	
Ballast replacement	New Ballast throughout. Assumes 3.18t per m	9,000	m	$ 170.00	$ 1,530,000.00	
Track tamping	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 25.00	$ 225,000.00	
OHW Traction System - Electrification of the line	8.6km route length plus passing loop (200m) and terminus platforms, substation.	1	Item	$ 9,750,000.00	$ 9,750,000.00	
Signalling - Electronic Interlocking System	8.6km route length plus passing loop (200m) and terminus platforms.	1	Item	$ 4,150,000.00	$ 4,150,000.00	
Level crossing upgrades	Resurfacing, drainage, upgrade of lights, booms, bells where required.	11	ea	$ 190,000.00	$ 2,090,000.00	
Service proofing		1	ea	$ 170,000.00	$ 170,000.00	
Track (Additional) - Mawson Place to Elizabeth St (Franklin Square)						$ 1,738,500.00
Initial Road Works	Remove existing Pavement, kerb stones, etc	200	m	$ 750.00	$ 150,000.00	
Single Track - Rail, Sleeper, Concrete to rail level	200m extension length	200	m	$ 1,300.00	$ 260,000.00	
Curved track (<30m Radius) Additional Cost	Additional set out, reinforcement, rail bending, etc	39	m	$ 1,500.00	$ 58,500.00	
Install OHLE	Foundation, Poles, Suspension, Curve Detailing, Cables & Return	200	m	$ 1,500.00	$ 300,000.00	
Traffic Management	Through construction period, diversions, road closure, etc	1	ea	$ 200,000.00	$ 200,000.00	
Tram / Pedestrian / Traffic interface works	Install new bollards, warning notices, line marking	200	m	$ 400.00	$ 80,000.00	
Intersection modification (Davey St x2)	Changes to signal priorities, removal of some turn functions, new signage	2	ea	$ 250,000.00	$ 500,000.00	
Service Proofing	200m extension length	200	m	$ 450.00	$ 90,000.00	
Urban Design & Landscaping	Allowance for pavement redesign, integration of light rail into streetscape, etc.	1	ea	$ 100,000.00	$ 100,000.00	
Structure						$ 3,100,000.00
Light rail depot	Including shed, stabling road, turnout to mainline	1	Item	$ 3,100,000.00	$ 3,100,000.00	
Stops						$ 3,188,400.00
Stops (Moonah, Derwent Park and Glenorchy)	Minimal platform structure, shelters, etc	3	ea	$ 150,000.00	$ 450,000.00	
Elizabeth Street terminus	Centrepiece station, integration to existing streetscape	1	ea	$ 400,000.00	$ 400,000.00	
Pathways / ramps	Approach ramps at end of platform - 30m per stn	120	m	$ 320.00	$ 38,400.00	
Pedestrian crossings	Basic passive cribs - 1 per station (not CBD stop)	3	ea	$ 10,000.00	$ 30,000.00	
Power to stops	Connection for Information displays, lighting	4	Item	$ 100,000.00	$ 400,000.00	
Bus interchange and park & ride facilities	Glenorchy and Moonah bus developments	1	Item	$ 1,800,000.00	$ 1,800,000.00	
Drainage	Drainage from platform to existing sewer or rail drainage	200	m	$ 350.00	$ 70,000.00	
Urban design / landscaping / bush care		**0.5%**	**Item**	**$ 39,089,200.00**	**$ 195,446.00**	**$ 195,446**
Total Contractor's Costs						**$ 39,285,000**
Client Costs						
Project management & project controls				5%		$ 1,964,300
Design				4.5%		$ 1,767,900
Other Costs						
Rolling stock - New electrically powered units		3	ea	$ 5,200,000.00		$ 15,600,000
Subtotal						**$ 58,617,000**
Contingency		12%				$ 7,034,000
Rolling Stock Contingency (New Units)		10%				$ 1,560,000
Total CAPEX Cost (2011 Rates)						**$ 67,211,000**
Plus Cost Increase Since 2011 Allowance		5%				**$ 70,572,000**

Hobart Light Rail

OHW and Electrical Units Rolling Stock - OOSM 03 - Narrow Gauge

Glenorchy to Elizabeth Street (Franklin Square)						
		Qty	Unit	Rate	Subtotal	Total
Track - Glenorchy to Mawson Place						$ 30,344,800.00
Clearing / Stripping	Formation stripping and grubbing, 5.4m width.	46,440	m²	$ 5.00	$ 232,200.00	
Remove existing rail and sleepers and stockpile	Remove existing track	8,600	m	$ 85.00	$ 731,000.00	
Subgrade improvement - replace unsuitable with imported, disposa of excavated material and geotextile to base	Allowance for 100% subgrade improvement, 4.4m minimum width. Excavation to be minimised with areas of good formation being rolled, compacted to form subgrade	37,840	m²	$ 95.00	$ 3,594,800.00	
Capping Layer	Install new capping layer. 4.4m width throughout.	37,840	m²	$ 20.00	$ 756,800.00	
Drainage	Allowance for drainage channels & cross drains	1,000	m	$ 350.00	$ 350,000.00	
Re establish swale drains	Swale drain either side of formation	8,600	m	$ 60.00	$ 516,000.00	
Subsoil drains along alignment	Assume requirement for 30% subsoil drains	2,580	m	$ 60.00	$ 154,800.00	
Subgrade preparation	Prepare subgrade. 4.4m width throughout.	37,840	m²	$ 5.00	$ 189,200.00	
Supply and install passing loop turnouts	1 x passing loop (2 turnouts) plus Terminus platforms	4	no	$ 250,000.00	$ 1,000,000.00	
Lay new sleepers	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 275.00	$ 2,475,000.00	
Lay existing or supplied rail	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 230.00	$ 2,070,000.00	
Rail grinding	Assume profiling required to match rail to LRV wheel profile, optimised for higher speed operation	9,000	m	$ 60.00	$ 540,000.00	
Ballast replacement	New Ballast throughout. Assumes 2.82t per m	9,000	m	$ 150.00	$ 1,350,000.00	
Track tamping	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 25.00	$ 225,000.00	
OHW Traction System - Electrification of the line	8.6km route length plus passing loop (200m) and terminus platforms, substation.	1	Item	$ 9,750,000.00	$ 9,750,000.00	
Signalling - Electronic Interlocking System	8.6km route length plus passing loop (200m) and terminus platforms.	1	Item	$ 4,150,000.00	$ 4,150,000.00	
Level crossing upgrades	Resurfacing, drainage, upgrade of lights, booms, bells where required.	11	ea	$ 190,000.00	$ 2,090,000.00	
Service proofing		1	ea	$ 170,000.00	$ 170,000.00	
Track (Additional) - Mawson Place to Elizabeth St (Franklin Square)						$ 1,738,500.00
Initial Road Works	Remove existing Pavement, kerb stones, etc	200	m	$ 750.00	$ 150,000.00	
Single Track - Rail, Sleeper, Concrete to rail level	200m extension length	200	m	$ 1,300.00	$ 260,000.00	
Curved track (<30m Radius) Additional Cost	Additional set out, reinforcement, rail bending, etc	39	m	$ 1,500.00	$ 58,500.00	
Install OHLE	Foundation, Poles, Suspension, Curve Detailing, Cables & Return	200	m	$ 1,500.00	$ 300,000.00	
Traffic Management	Through construction period, diversions, road closure, etc	1	ea	$ 200,000.00	$ 200,000.00	
Tram / Pedestrian / Traffic interface works	Install new bollards, warning notices, line marking	200	m	$ 400.00	$ 80,000.00	
Intersection modification (Davey St x2)	Changes to signal priorities, removal of some turn functions, new signage	2	ea	$ 250,000.00	$ 500,000.00	
Service Proofing	200m extension length	200	m	$ 450.00	$ 90,000.00	
Urban Design & Landscaping	Allowance for pavement redesign, integration of light rail into streetscape, etc.	1	ea	$ 100,000.00	$ 100,000.00	
Structure						$ 3,100,000.00
Light rail depot	Including shed, stabling road, turnout to mainline	1	Item	$ 3,100,000.00	$ 3,100,000.00	
Stops						$ 3,475,500.00
Stops (New Town, Moonah, Derwent Park and Glenorchy)	Minimal platform structure, shelters, etc	4	ea	$ 150,000.00	$ 600,000.00	
Elizabeth Street terminus	Centrepiece station, integration to existing streetscape	1	ea	$ 400,000.00	$ 400,000.00	
Pathways / ramps	Approach ramps at end of platform - 30m per stn	150	m	$ 320.00	$ 48,000.00	
Pedestrian crossings	Basic passive cribs -1 per station (not CBD stop)	4	ea	$ 10,000.00	$ 40,000.00	
Power to stops	Connection for Information displays, lighting	5	Item	$ 100,000.00	$ 500,000.00	
Bus interchange and park & ride facilities	Glenorchy and Moonah bus developments	1	Item	$ 1,800,000.00	$ 1,800,000.00	
Drainage	Drainage from platform to existing sewer or rail drainage	250	m	$ 350.00	$ 87,500.00	
Urban design / landscaping / bush care		**0.5%**	**Item**	**$ 38,658,800.00**	**$ 193,294.00**	**$ 193,294**
Total Contractor's Costs						**$ 38,852,000**
Client Costs						
Project management & project controls				5.0%		$ 1,942,600
Design				4.5%		$ 1,748,400
Other Costs						
Rolling stock - New electrically powered units		3	ea	$ 5,720,000.00		$ 17,160,000
Subtotal						**$ 59,703,000**
Contingency		12%				$ 7,164,000
Rolling Stock Contingency (New Units)		10%				$ 1,716,000
Total CAPEX Cost (2011 Rates)						**$ 68,583,000**
Plus Cost Increase Since 2011 Allowance		5%				**$ 72,012,000**

Hobart Light Rail

OHW and Electrical Units Rolling Stock - OOSM 03 - Standard Gauge with Dual Gauge Provision

Glenorchy to Elizabeth Street (Franklin Square)						
		Qty	Unit	Rate	Subtotal	Total
Track - Glenorchy to Mawson Place						$ 31,062,300.00
Clearing / Stripping	Formation stripping and grubbing, 5.9m width.	50,740	m²	$ 5.00	$ 253,700.00	
Remove existing rail and sleepers and stockpile	Remove existing track	8,600	m	$ 85.00	$ 731,000.00	
Subgrade improvement - replace unsuitable with imported, disposal of excavated material and geotextile to base	Allowance for 100% subgrade improvement, 4.9m minimum width. Excavation to be minimised with areas of good formation being rolled, compacted to form subgrade	42,140	m²	$ 95.00	$ 4,003,300.00	
Capping Layer	Install new capping layer. 4.9m width throughout.	42,140	m²	$ 20.00	$ 842,800.00	
Drainage	Allowance for drainage channels & cross drains	1,000	m	$ 350.00	$ 350,000.00	
Re establish swale drains	Swale drain either side of formation	8,600	m	$ 60.00	$ 516,000.00	
Subsoil drains along alignment	Assume requirement for 30% subsoil drains	2,580	m	$ 60.00	$ 154,800.00	
Subgrade preparation	Prepare subgrade. 4.9m width throughout.	42,140	m²	$ 5.00	$ 210,700.00	
Supply and install passing loop turnouts	1 x passing loop (2 turnouts) plus Terminus platforms	4	no	$ 250,000.00	$ 1,000,000.00	
Lay new sleepers	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 275.00	$ 2,475,000.00	
Lay existing or supplied rail	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 230.00	$ 2,070,000.00	
Rail grinding	Assume profiling required to match rail to LRV wheel profile, optimised for higher speed operation	9,000	m	$ 60.00	$ 540,000.00	
Ballast replacement	New Ballast throughout. Assumes 3.18t per m	9,000	m	$ 170.00	$ 1,530,000.00	
Track tamping	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 25.00	$ 225,000.00	
OHW Traction System - Electrification of the line	8.6km route length plus passing loop (200m) and terminus platforms, substation.	1	Item	$ 9,750,000.00	$ 9,750,000.00	
Signalling - Electronic Interlocking System	8.6km route length plus passing loop (200m) and terminus platforms.	1	Item	$ 4,150,000.00	$ 4,150,000.00	
Level crossing upgrades	Resurfacing, drainage, upgrade of lights, booms, bells where required.	11	ea	$ 190,000.00	$ 2,090,000.00	
Service proofing		1	ea	$ 170,000.00	$ 170,000.00	
Track (Additional) - Mawson Place to Elizabeth St (Franklin Square)						**$ 1,738,500.00**
Initial Road Works	Remove existing Pavement, kerb stones, etc	200	m	$ 750.00	$ 150,000.00	
Single Track - Rail, Sleeper, Concrete to rail level	200m extension length	200	m	$ 1,300.00	$ 260,000.00	
Curved track (<30m Radius) Additional Cost	Additional set out, reinforcement, rail bending, etc	39	m	$ 1,500.00	$ 58,500.00	
Install OHLE	Foundation, Poles, Suspension, Curve Detailing, Cables & Return	200	m	$ 1,500.00	$ 300,000.00	
Traffic Management	Through construction period, diversions, road closure, etc	1	ea	$ 200,000.00	$ 200,000.00	
Tram / Pedestrian / Traffic interface works	Install new bollards, warning notices, line marking	200	m	$ 400.00	$ 80,000.00	
Intersection modification (Davey St x2)	Changes to signal priorities, removal of some turn functions, new signage	2	ea	$ 250,000.00	$ 500,000.00	
Service Proofing	200m extension length	200	m	$ 450.00	$ 90,000.00	
Urban Design & Landscaping	Allowance for pavement redesign, integration of light rail into streetscape, etc.	1	ea	$ 100,000.00	$ 100,000.00	
Structure						**$ 3,100,000.00**
Light rail depot	Including shed, stabling road, turnout to mainline	1	Item	$ 3,100,000.00	$ 3,100,000.00	
Stops						**$ 3,475,500.00**
Stops (New Town, Moonah, Derwent Park and Glenorchy)	Minimal platform structure, shelters, etc	4	ea	$ 150,000.00	$ 600,000.00	
Elizabeth Street terminus	Centrepiece station, integration to existing streetscape	1	ea	$ 400,000.00	$ 400,000.00	
Pathways / ramps	Approach ramps at end of platform - 30m per stn	150	m	$ 320.00	$ 48,000.00	
Pedestrian crossings	Basic passive cribs - 1 per station (not CBD stop)	4	ea	$ 10,000.00	$ 40,000.00	
Power to stops	Connection for Information displays, lighting	5	Item	$ 100,000.00	$ 500,000.00	
Bus interchange and park & ride facilities	Glenorchy and Moonah bus developments	1	Item	$ 1,800,000.00	$ 1,800,000.00	
Drainage	Drainage from platform to existing sewer or rail drainage	250	m	$ 350.00	$ 87,500.00	
Urban design / landscaping / bush care		**0.5%**	**Item**	**$ 39,376,300.00**	**$ 196,881.50**	**$ 196,882**
Total Contractor's Costs						**$ 39,573,000**
Client Costs						
Project management & project controls				5%		$ 1,978,700
Design				4.5%		$ 1,780,800
Other Costs						
Rolling stock - New electrically powered units		3	ea	$ 5,200,000.00		$ 15,600,000
Subtotal						**$ 58,933,000**
Contingency		12%				$ 7,072,000
Rolling Stock Contingency (New Units)		10%				$ 1,560,000
Total CAPEX Cost (2011 Rates)						**$ 67,565,000**
Plus Cost Increase Since 2011 Allowance		5%				**$ 70,943,000**

Hobart Light Rail

OHW and Electrical Units Rolling Stock - OOSM 04 - Narrow Gauge

Glenorchy to Elizabeth Street (Franklin Square)						
		Qty	Unit	Rate	Subtotal	Total
Track - Glenorchy to Mawson Place						$ 30,344,800.00
Clearing / Stripping	Formation stripping and grubbing, 5.4m width.	46,440	m²	$ 5.00	$ 232,200.00	
Remove existing rail and sleepers and stockpile	Remove existing track	8,600	m	$ 85.00	$ 731,000.00	
Subgrade improvement - replace unsuitable with imported, disposa of excavated material and geotextile to base	Allowance for 100% subgrade improvement, 4.4m minimum width. Excavation to be minimised with areas of good formation being rolled, compacted to form subgrade	37,840	m²	$ 95.00	$ 3,594,800.00	
Capping Layer	Install new capping layer. 4.4m width throughout.	37,840	m²	$ 20.00	$ 756,800.00	
Drainage	Allowance for drainage channels & cross drains	1,000	m	$ 350.00	$ 350,000.00	
Re establish swale drains	Swale drain either side of formation	8,600	m	$ 60.00	$ 516,000.00	
Subsoil drains along alignment	Assume requirement for 30% subsoil drains	2,580	m	$ 60.00	$ 154,800.00	
Subgrade preparation	Prepare subgrade. 4.4m width throughout.	37,840	m²	$ 5.00	$ 189,200.00	
Supply and install passing loop turnouts	1 x passing loop (2 turnouts) plus Terminus platforms	4	no	$ 250,000.00	$ 1,000,000.00	
Lay new sleepers	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 275.00	$ 2,475,000.00	
Lay existing or supplied rail	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 230.00	$ 2,070,000.00	
Rail grinding	Assume profiling required to match rail to LRV wheel profile, optimised for higher speed operation	9,000	m	$ 60.00	$ 540,000.00	
Ballast replacement	New Ballast throughout. Assumes 2.82t per m	9,000	m	$ 150.00	$ 1,350,000.00	
Track tamping	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 25.00	$ 225,000.00	
OHW Traction System - Electrification of the line	8.6km route length plus passing loop (200m) and terminus platforms, substation.	1	Item	$ 9,750,000.00	$ 9,750,000.00	
Signalling - Electronic Interlocking System	8.6km route length plus passing loop (200m) and terminus platforms.	1	Item	$ 4,150,000.00	$ 4,150,000.00	
Level crossing upgrades	Resurfacing, drainage, upgrade of lights, booms, bells where required.	11	ea	$ 190,000.00	$ 2,090,000.00	
Service proofing		1	ea	$ 170,000.00	$ 170,000.00	
Track (Additional) - Mawson Place to Elizabeth St (Franklin Square)						$ 1,738,500.00
Initial Road Works	Remove existing Pavement, kerb stones, etc	200	m	$ 750.00	$ 150,000.00	
Single Track - Rail, Sleeper, Concrete to rail level	200m extension length	200	m	$ 1,300.00	$ 260,000.00	
Curved track (<30m Radius) Additional Cost	Additional set out, reinforcement, rail bending, etc	39	m	$ 1,500.00	$ 58,500.00	
Install OHLE	Foundation, Poles, Suspension, Curve Detailing, Cables & Return	200	m	$ 1,500.00	$ 300,000.00	
Traffic Management	Through construction period, diversions, road closure, etc	1	ea	$ 200,000.00	$ 200,000.00	
Tram / Pedestrian / Traffic interface works	Install new bollards, warning notices, line marking	200	m	$ 400.00	$ 80,000.00	
Intersection modification (Davey St x2)	Changes to signal priorities, removal of some turn functions, new signage	2	ea	$ 250,000.00	$ 500,000.00	
Service Proofing	200m extension length	200	m	$ 450.00	$ 90,000.00	
Urban Design & Landscaping	Allowance for pavement redesign, integration of light rail into streetscape, etc.	1	ea	$ 100,000.00	$ 100,000.00	
Structure						$ 3,100,000.00
Light rail depot	Including shed, stabling road, turnout to mainline	1	Item	$ 3,100,000.00	$ 3,100,000.00	
Stops						$ 3,762,600.00
Stops (Macquarie Park, New Town, Moonah, Derwent Park and Glenorchy)	Minimal platform structure, shelters, etc	5	ea	$ 150,000.00	$ 750,000.00	
Elizabeth Street terminus	Centrepiece station, integration to existing streetscape	1	ea	$ 400,000.00	$ 400,000.00	
Pathways / ramps	Approach ramps at end of platform - 30m per stn	180	m	$ 320.00	$ 57,600.00	
Pedestrian crossings	Basic passive cribs -1 per station (not CBD stop)	5	ea	$ 10,000.00	$ 50,000.00	
Power to stops	Connection for Information displays, lighting	6	Item	$ 100,000.00	$ 600,000.00	
Bus interchange and park & ride facilities	Glenorchy and Moonah bus developments	1	Item	$ 1,800,000.00	$ 1,800,000.00	
Drainage	Drainage from platform to existing sewer or rail drainage	300	m	$ 350.00	$ 105,000.00	
Urban design / landscaping / bush care		**0.5%**	**Item**	**$ 38,945,900.00**	**$ 194,729.50**	**$ 194,730**
Total Contractor's Costs						**$ 39,141,000**
Client Costs						
Project management & project controls				5.0%		$ 1,957,100
Design				4.5%		$ 1,761,400
Other Costs						
Rolling stock - New electrically powered units		4	ea	$ 5,720,000.00		$ 22,880,000
Subtotal						**$ 65,740,000**
Contingency		12%				$ 7,889,000
Rolling Stock Contingency (New Units)		10%				$ 2,288,000
Total CAPEX Cost (2011 Rates)						**$ 75,917,000**
Plus Cost Increase Since 2011 Allowance		5%				**$ 79,713,000**

Hobart Light Rail

OHW and Electrical Units Rolling Stock - OOSM 04 - Standard Gauge with Dual Gauge Provision

Glenorchy to Elizabeth Street (Franklin Square)						
		Qty	Unit	Rate	Subtotal	Total
Track - Glenorchy to Mawson Place						$ 31,062,300.00
Clearing / Stripping	Formation stripping and grubbing, 5.9m width.	50,740	m²	$ 5.00	$ 253,700.00	
Remove existing rail and sleepers and stockpile	Remove existing track	8,600	m	$ 85.00	$ 731,000.00	
Subgrade improvement - replace unsuitable with imported, disposal of excavated material and geotextile to base	Allowance for 100% subgrade improvement, 4.9m minimum width. Excavation to be minimised with areas of good formation being rolled, compacted to form subgrade	42,140	m²	$ 95.00	$ 4,003,300.00	
Capping Layer	Install new capping layer. 4.9m width throughout.	42,140	m²	$ 20.00	$ 842,800.00	
Drainage	Allowance for drainage channels & cross drains	1,000	m	$ 350.00	$ 350,000.00	
Re establish swale drains	Swale drain either side of formation	8,600	m	$ 60.00	$ 516,000.00	
Subsoil drains along alignment	Assume requirement for 30% subsoil drains	2,580	m	$ 60.00	$ 154,800.00	
Subgrade preparation	Prepare subgrade. 4.9m width throughout.	42,140	m²	$ 5.00	$ 210,700.00	
Supply and install passing loop turnouts	1 x passing loop (2 turnouts) plus Terminus platforms	4	no	$ 250,000.00	$ 1,000,000.00	
Lay new sleepers	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 275.00	$ 2,475,000.00	
Lay existing or supplied rail	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 230.00	$ 2,070,000.00	
Rail grinding	Assume profiling required to match rail to LRV wheel profile, optimised for higher speed operation	9,000	m	$ 60.00	$ 540,000.00	
Ballast replacement	New Ballast throughout. Assumes 3.18t per m	9,000	m	$ 170.00	$ 1,530,000.00	
Track tamping	8.6km route length plus passing loop (200m) and terminus platforms	9,000	m	$ 25.00	$ 225,000.00	
OHW Traction System - Electrification of the line	8.6km route length plus passing loop (200m) and terminus platforms, substation.	1	Item	$ 9,750,000.00	$ 9,750,000.00	
Signalling - Electronic Interlocking System	8.6km route length plus passing loop (200m) and terminus platforms.	1	Item	$ 4,150,000.00	$ 4,150,000.00	
Level crossing upgrades	Resurfacing, drainage, upgrade of lights, booms, bells where required.	11	ea	$ 190,000.00	$ 2,090,000.00	
Service proofing		1	ea	$ 170,000.00	$ 170,000.00	
Track (Additional) - Mawson Place to Elizabeth St (Franklin Square)						$ 1,738,500.00
Initial Road Works	Remove existing Pavement, kerb stones, etc	200	m	$ 750.00	$ 150,000.00	
Single Track - Rail, Sleeper, Concrete to rail level	200m extension length	200	m	$ 1,300.00	$ 260,000.00	
Curved track (<30m Radius) Additional Cost	Additional set out, reinforcement, rail bending, etc	39	m	$ 1,500.00	$ 58,500.00	
Install OHLE	Foundation, Poles, Suspension, Curve Detailing, Cables & Return	200	m	$ 1,500.00	$ 300,000.00	
Traffic Management	Through construction period, diversions, road closure, etc	1	ea	$ 200,000.00	$ 200,000.00	
Tram / Pedestrian / Traffic interface works	Install new bollards, warning notices, line marking	200	m	$ 400.00	$ 80,000.00	
Intersection modification (Davey St x2)	Changes to signal priorities, removal of some turn functions, new signage	2	ea	$ 250,000.00	$ 500,000.00	
Service Proofing	200m extension length	200	m	$ 450.00	$ 90,000.00	
Urban Design & Landscaping	Allowance for pavement redesign, integration of light rail into streetscape, etc.	1	ea	$ 100,000.00	$ 100,000.00	
Structure						$ 3,100,000.00
Light rail depot	Including shed, stabling road, turnout to mainline	1	Item	$ 3,100,000.00	$ 3,100,000.00	
Stops						$ 3,762,600.00
Stops (Macquarie Park, New Town, Moonah, Derwent Park and Glenorchy)	Minimal platform structure, shelters, etc	5	ea	$ 150,000.00	$ 750,000.00	
Elizabeth Street terminus	Centrepiece station, integration to existing streetscape	1	ea	$ 400,000.00	$ 400,000.00	
Pathways / ramps	Approach ramps at end of platform - 30m per stn	180	m	$ 320.00	$ 57,600.00	
Pedestrian crossings	Basic passive cribs - 1 per station (not CBD stop)	5	ea	$ 10,000.00	$ 50,000.00	
Power to stops	Connection for Information displays, lighting	6	Item	$ 100,000.00	$ 600,000.00	
Bus interchange and park & ride facilities	Glenorchy and Moonah bus developments	1	Item	$ 1,800,000.00	$ 1,800,000.00	
Drainage	Drainage from platform to existing sewer or rail drainage	300	m	$ 350.00	$ 105,000.00	
Urban design / landscaping / bush care		**0.5%**	**Item**	**$ 39,663,400.00**	**$ 198,317.00**	**$ 198,317**
Total Contractor's Costs						**$ 39,862,000**
Client Costs						
Project management & project controls				5%		$ 1,993,100
Design				4.5%		$ 1,793,800
Other Costs						
Rolling stock - New electrically powered units		4	ea	$ 5,200,000.00		$ 20,800,000
Subtotal						**$ 64,449,000**
Contingency		12%				$ 7,734,000
Rolling Stock Contingency (New Units)		10%				$ 2,080,000
Total CAPEX Cost (2011 Rates)						**$ 74,263,000**
Plus Cost Increase Since 2011 Allowance		5%				**$ 77,976,000**

Hobart Light Rail

Maintenance costs for rail assets (new installation)

(First FiveYears)	Qty	Unit	Rate	Subtotal	Total
Track					3,400
Ballast cleaning (full)	-	m	400	-	
Track tamping	500	m	7	3,400	
Ballast re-surfacing	-	t	160	-	
Rail grinding	-	m	37	-	
Rail replacement	-	m	300	-	
Re-sleepering (5% per annum)	-	ea	230	-	
Generally					397,600
Allow for bridge inspection works (every five years)	5	No	10,000	50,000	
Anti-graffiti paint treatment to bridges etc.	1,600	m2	25	40,000	
Graffiti removal	1,600	m2	10	16,000	
Weeding and general cleanup of track length (8,600 metres) (three out of five years)	36	Months	2,900	104,400	
Repairs/replacement to trackside fencing (say 5% per annum)	2,080	m	90	187,200	
Subtotal					**$ 401,000**
Contingency			20.00%		80,200
Subtotal					**$ 481,200**
Rail Corporation's Overheads			5.00%		24,100
Total OPEX Cost	**5**	**years**			**$ 505,300**
	1	year			**$ 101,060**

(Years 5-10)	Qty	Unit	Rate	Subtotal	Total
Track					258,200
Ballast cleaning (full)	-	m	400	-	
Track tamping	9,000	m	7	61,200	
Ballast re-surfacing	1,000	t	160	160,000	
Rail grinding	1,000	m	37	37,000	
Rail replacement	-	m	300	-	
Re-sleepering (5% per annum)	-	ea	230	-	
Generally					397,600
Allow for bridge inspection works (every five years)	5	No	10,000	50,000	
Anti-graffiti paint treatment to bridges etc.	1,600	m2	25	40,000	
Graffiti removal	1,600	m2	10	16,000	
Weeding and general cleanup of track length (8,600 metres) (three out of five years)	36	Months	2,900	104,400	
Repairs/replacement to trackside fencing (say 5% per annum)	2,080	m	90	187,200	
Subtotal					**$ 655,800**
Contingency			20.00%		131,200
Subtotal					**$ 787,000**
Rail Corporation's Overheads			5.00%		39,400
Total OPEX Cost	**5**	**years**			**$ 826,400**
	1	year			**$ 165,280**

(Years 10-20)	Qty	Unit	Rate	Subtotal	Total
Track					1,384,200
Ballast cleaning (full)	-	m	400	-	
Track tamping	9,000	m	7	61,200	
Ballast re-surfacing	1,500	t	160	240,000	
Rail grinding	9,000	m	37	333,000	
Rail replacement	2,500	m	300	750,000	
Re-sleepering (5% per annum)	-	ea	230	-	
Generally					397,600
Allow for bridge inspection works (every five years)	5	No	10,000	50,000	
Anti-graffiti paint treatment to bridges etc.	1,600	m2	25	40,000	
Graffiti removal	1,600	m2	10	16,000	
Weeding and general cleanup of track length (8,600 metres) (three out of five years)	36	Months	2,900	104,400	
Repairs/replacement to trackside fencing (say 5% per annum)	2,080	m	90	187,200	
Subtotal					**$ 1,781,800**
Contingency			20.00%		356,400
Subtotal					**$ 2,138,200**
Rail Corporation's Overheads			5.00%		107,000
Total OPEX Cost	**5**	**years**			**$ 2,245,200**
	1	year			**$ 449,040**

(Years 20-25) and Beyond	Qty	Unit	Rate	Subtotal	Total
Track					4,909,200
Ballast cleaning (full)	4,500	m	400	1,800,000	
Track tamping	9,000	m	7	61,200	
Ballast re-surfacing	3,500	t	160	560,000	
Rail grinding	9,000	m	37	333,000	
Rail replacement	4,500	m	300	1,350,000	
Re-sleepering (5% per annum)	3,500	ea	230	805,000	
Generally					397,600
Allow for bridge inspection works (every five years)	5	No	10,000	50,000	
Anti-graffiti paint treatment to bridges etc.	1,600	m2	25	40,000	
Graffiti removal	1,600	m2	10	16,000	
Weeding and general cleanup of track length (8,600 metres) (three out of five years)	36	Months	2,900	104,400	
Repairs/replacement to trackside fencing (say 5% per annum)	2,080	m	90	187,200	
Subtotal					**$ 5,306,800**
Contingency			20.00%		1,061,400
Subtotal					**$ 6,368,200**
Rail Corporation's Overheads			5.00%		318,500
Total OPEX Cost	**5**	**years**			**$ 6,686,700**
	1	year			**$ 1,337,340**

Hobart Light Rail

Operational costs for Hobart Light Rail per annum

Costs per annum - OOSM 01 to 03					
	Qty	Unit	Rate	Subtotal	Total
Rail operations					2,163,800
Drivers	7	no	85,000	595,000	
Staff	3	no	85,000	255,000	
General Running Costs	1	Item	213,750	213,750	
Rolling Stock maintenance	1	Item	600,000	600,000	
Other	1	Item	500,000	500,000	
				-	
Subtotal					**$ 2,163,800**
					-
Total cost per annum	**1**	**year**			**$ 2,163,800**

Costs per annum - OOSM 04					
	Qty	Unit	Rate	Subtotal	Total
Rail operations					2,478,800
Drivers	8	no	85,000	680,000	
Staff	3	no	85,000	255,000	
General Running Costs	1	Item	243,750	243,750	
Rolling Stock maintenance	1	Item	800,000	800,000	
Other	1	Item	500,000	500,000	
				-	
Subtotal					**$ 2,478,800**
					-
Total cost per annum	**1**	**year**			**$ 2,478,800**

Hobart Light Rail

Track Construction - City Station Location

Elizabeth Street (Franklin Square - Between Davey and Macquarie Streets)					
Track (Additional) - Elizabeth St to Mawson Place					**$ 1,738,500.00**
Initial Road Works (Remove existing Pavement, etc)	200	m	$ 750.00	$ 150,000.00	
Single Track - Rail, Sleeper, Concrete to rail level	200	m	$ 1,300.00	$ 260,000.00	
Curved track (<30m Radius) Additional Cost	39	m	$ 1,500.00	$ 58,500.00	
OHLE - Foundation, Poles, Suspension, Curve Detailing, Cables & Return	200	m	$ 1,500.00	$ 300,000.00	
Traffic Management	1	ea	$ 200,000.00	$ 200,000.00	
Tram / Pedestrian / Traffic interface works	200	m	$ 400.00	$ 80,000.00	
Intersection modification (Davey St x2)	2	ea	$ 250,000.00	$ 500,000.00	
Service Proofing	200	m	$ 450.00	$ 90,000.00	
Urban Design & Landscaping	1	ea	$ 100,000.00	$ 100,000.00	

Elizabeth Street (South - Between Morrison and Elizabeth Streets)					
Track (Additional) - Elizabeth St to Mawson Place					**$ 1,430,000.00**
Initial Road Works (Remove existing Pavement, etc)	200	m	$ 750.00	$ 150,000.00	
Single Track - Rail, Sleeper, Concrete to rail level	200	m	$ 1,300.00	$ 260,000.00	
Curved track (<30m Radius) Additional Cost	100	m	$ 1,500.00	$ 150,000.00	
OHLE - Foundation, Poles, Suspension, Curve Detailing, Cables & Return	200	m	$ 1,500.00	$ 300,000.00	
Traffic Management	1	ea	$ 50,000.00	$ 50,000.00	
Tram / Pedestrian / Traffic interface works	200	m	$ 400.00	$ 80,000.00	
Intersection modification (Davey St x2)	1	ea	$ 250,000.00	$ 250,000.00	
Service Proofing	200	m	$ 450.00	$ 90,000.00	
Urban Design & Landscaping	1	ea	$ 100,000.00	$ 100,000.00	

COSTS ALREADY INCLUDED IN OOSM 01 to 04 ESTIMATES

Hobart Light Rail

Optional Upgrade to Dual Gauge - To maintain narrow gauge freight & Heritage services to Hobart Rail Yard

Hobart Rail Yard to Glenorchy					
	Qty	**Unit**	**Rate**	**Subtotal**	**Total**
Track - Future Optional Upgrade					**$ 2,620,000.00**
Install new components to existing sleepers	9,000	m	$ 90.00	$ 810,000.00	
Lay 1 x existing or supplied rail	9,000	m	$ 115.00	$ 1,035,000.00	
Install new or modify existing passing loop turnouts	2	no	$ 125,000.00	$ 250,000.00	
Signalling - Test & Commission	1	Item	$ 250,000.00	$ 250,000.00	
Level crossing - remove & reseal	11	ea	$ 25,000.00	$ 275,000.00	
Total Contractor's Costs					**$ 2,620,000**
Client Costs					
Project management & project controls			5%		$ 131,000
Subtotal					**$ 2,751,000**
Total CAPEX Cost (2013 Rates)					**$ 2,751,000**
					$ 299,021.74

ONLY FOR INFORMATION ON COSTS IF A DUAL GAUGE IS NEEDED TO RUN HERITAGE/FREIGHT IN ADDITION TO STANDARD GAUGE

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