Hobart to Northern Suburbs Light Rail Business Case

A report detailing the findings of the third stage of the project

Prepared for the Department of Infrastructure Energy and Resources

July 2011

ACIL Tasman

Economics Policy Strategy

Reliance and Disclaimer

ACIL Tasman Pty Ltd

ABN 68 102 652 148
Internet www.aciltasman.com.au

Melbourne (Head Office)
Level 4, 114 William Street
Melbourne VIC 3000

Telephone (+61 3) 9604 4400
Facsimile (+61 3) 9604 4455
Email melbourne@aciltasman.com.au

Brisbane
Level 15, 127 Creek Street
Brisbane QLD 4000
GPO Box 32
Brisbane QLD 4001

Telephone (+61 7) 3009 8700
Facsimile (+61 7) 3009 8799
Email brisbane@aciltasman.com.au

Canberra
Level 1, 33 Ainslie Place
Canberra City ACT 2600
GPO Box 1322
Canberra ACT 2601

Telephone (+61 2) 6103 8200
Facsimile (+61 2) 6103 8233
Email canberra@aciltasman.com.au

Perth
Centa Building C2, 118 Railway Street
West Perth WA 6005

Telephone (+61 8) 9449 9600
Facsimile (+61 8) 9322 3955
Email perth@aciltasman.com.au

Sydney
PO Box 1554
Double Bay NSW 1360

Telephone (+61 2) 9389 7842
Facsimile (+61 2) 8080 8142
Email sydney@aciltasman.com.au

For information on this report

Please contact:

Nick Wills-Johnson
Telephone (08) 9449 9616
Mobile 0404 665 219
Email n.wills-johnson@aciltasman.com.au

Contributing team members

Nick Wills-Johnson
Simon Sagerer
David Greig
Ken Willett
Jacqui Allen (SEMF)

Contents

List of boxes

List of figures

List of tables

Executive summary

ACIL Tasman, Hyder Consulting and SEMF have been appointed by the Department of Infrastructure, Energy and Resources (DIER) to assess the business case for a light rail passenger system which makes use of the existing rail corridor between Hobart and Brighton. The study consists of three distinct stages:

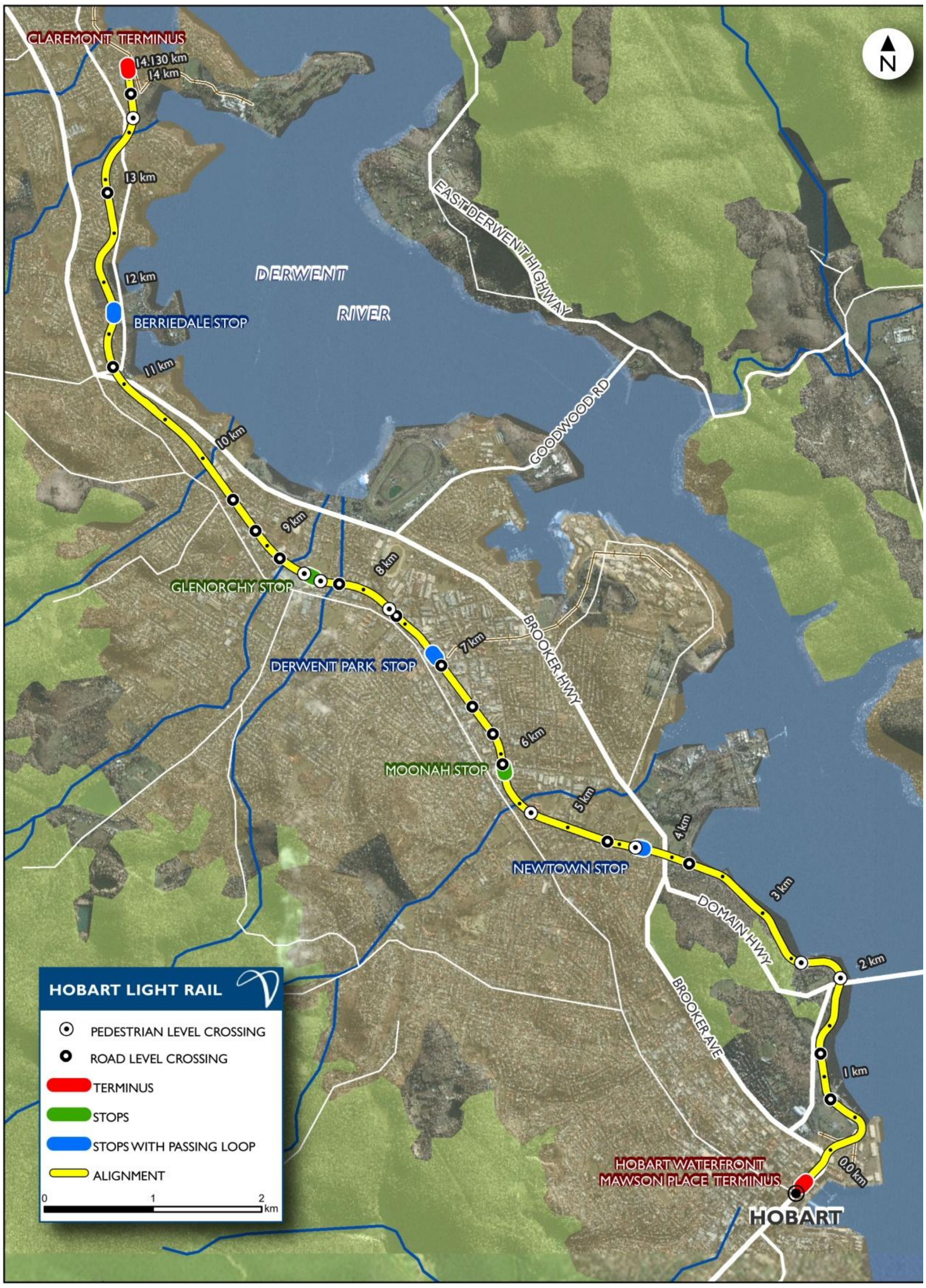
- A background stage which describes the context and setting for the project as a whole and sets broad parameters for the remainder of the project. One key outcome from this stage was a finding that extending the line past Claremont is likely to incur significant costs relative to likely benefits, and thus a recommendation was made to consider in detail a service from Mawson Place to Claremont in future stages. This is the Northern Suburbs Light Rail System (NSLRS) described in this report.
- A stage which develops optimal operating service models (OOSMs) for the light rail system.
- A stage which calculates the economic costs and benefits associated with the optimal operating service models.

A final stage of the project will bring the reports for each of these stages together into a single final report.

This report provides an overview of the third phase of the project, which incorporates a detailed demand analysis, and ascertains the net benefits of the proposed railway, taking into consideration the costs of the optimal operating service models derived in Stage Two. Figure ES1 (overleaf) provides an overview of the NSLRS, and is drawn from the Stage Two report.

The analysis is grounded in notions of consumer surplus. We develop demand curves for all modes of transport before and after the introduction of the NSLRS using a spatial model of total resource cost minimisation on the part of consumers. Variance in the inputs gives rise to large numbers of price-quantity points for each mode and regression analysis is used to fit a demand curve to these points. We include in our resource costs of travel the cash costs, time costs and various externalities, thus internalising these costs into the consumer decision. We calculate the consumer surplus associated with each demand curve, and then compare the overall consumer surplus situation prior to and after the introduction of the NSLRS. The difference is the benefit of the system in each scenario examined, which is then compared (after subtracting any required subsidies) with the costs of developing the NSLRS.

Figure ES 1 **NSLRS – proposed alignment**



Source: Stage Two report

The model is based upon a notion of cost minimisation, but railways can generate patronage above and beyond that which a model of their cost to users would predict, because of the relative attractiveness of railways for users compared to other public transport modes. One key example is Perth, where the replacement of a bus route (using dedicated lanes for part of the distance) with a train down the centre of the Kwinana Freeway resulted in patronage on the route more than tripling (Newman, 2011). We want to be able to account for this "sparks effect", and we thus calibrate the model to produce a modal share for rail which matches this very strong sparks effect in Perth.

However, we also recognise that, since there is limited understanding of what drives the sparks effect (or at least, a sparks effect this large), it is difficult to ensure that it occurs in Hobart. We thus examine a version of the model where the effects of this strong sparks effect have been removed. Further, we also examine smaller potential sparks effects to ascertain how they affect the viability of the NSLRS. The results of our analysis in regards to the strong sparks effects and no sparks effects cases (in effect, the end points of likely demand scenarios) are shown in Table ES1.

Table ES 1 **Benefit cost analysis results**

	Strong Sparks Effect		No Sparks Effect	
	Benefit cost ratio	Net benefit ($ mil)	Benefit cost ratio	Net benefit ($ mil)
OOSM 1 (diesel rolling stock)				
4 % disc rate	1.11	22.7	0.0	-268.8
7 % disc rate	1.10	14.5	0.0	-191.5
10 % disc rate	1.09	9.9	0.0	-144.2
OOSM 2 (electric rolling stock)				
4 % disc rate	0.97	-7.3	0.0	-299.6
7 % disc rate	0.95	-7.4	0.0	-213.8
10 % disc rate	0.94	-6.9	0.0	-161.4

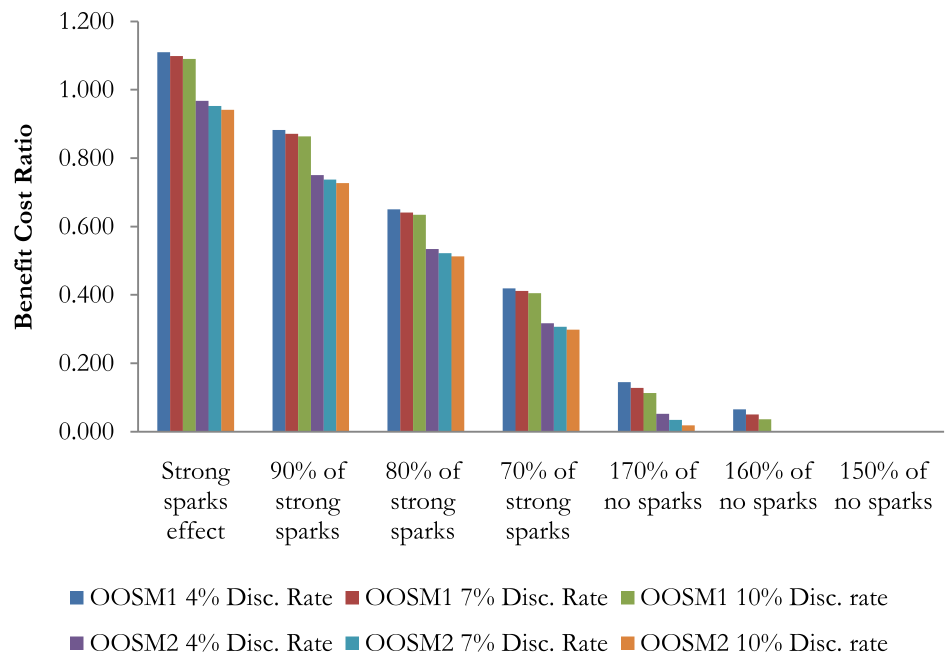
The difference between the strong sparks effect and no sparks effect cases is stark; the consumer surplus in the latter case is only roughly a fifth of that prevailing in the former case, and is insufficient to overcome the subsidy required to operate the NSLRS. The result is a negative stream of benefits. In benefit cost terms, this means that, while a strong sparks effect can generate a benefit cost ratio that just exceeds one, the lack of a sparks effect generates a cost benefit ratio of zero, and very large social costs.

We explore this further by examining intermediate sparks effects of different sizes, instead of only considering the end points of likely demand; the strong sparks effects and no sparks effects cases. We do this by decreasing (or increasing) patronage and consumer surplus from the levels found for the strong and no sparks effects cases (respectively). The patronage and consumer surplus assumptions in these various cases are shown in Table ES2, and the resultant cost benefit ratios in Figure ES2. Note in figure ES2 that the benefit cost ratio for all levels of demand lower than 150 percent of the no sparks case is zero, and hence we do not show levels of demand below this level.

Table ES 2 **Patronage and consumer surplus (per annum)**

	Patronage (weekly)					Consumer surplus ($ mil per annum)				
	Year 1	Year 5	Year 10	Year 20	Year 30	Year 1	Year 5	Year 10	Year 20	Year 30
Strong sparks effect	90,188	92,588	110,607	117,408	123,832	$11.123	$12.724	$13.468	$14.296	$15.078
90% of strong sparks	81,169	83,330	99,546	105,667	111,448	$10.011	$11.452	$12.121	$12.866	$13.570
80% of strong sparks	72,150	74,071	88,486	93,926	99,065	$8.898	$10.179	$10.774	$11.436	$12.062
70% of strong sparks	63,132	64,812	77,425	82,185	86,682	$7.786	$8.907	$9.427	$10.007	$10.554
170% of no sparks	42,950	44,094	66,750	70,854	74,731	$3.639	$4.736	$5.141	$5.457	$5.756
160% of no sparks	40,424	41,500	62,823	66,686	70,335	$3.425	$4.457	$4.839	$5.136	$5.417
150% of no sparks	37,897	38,906	58,897	62,518	65,939	$3.211	$4.179	$4.536	$4.815	$5.078
140% of no sparks	35,371	36,312	54,971	58,350	61,543	$2.997	$3.900	$4.234	$4.494	$4.740
130% of no sparks	32,844	33,719	51,044	54,182	57,147	$2.783	$3.621	$3.931	$4.173	$4.401
120% of no sparks	30,318	31,125	47,118	50,015	52,751	$2.569	$3.343	$3.629	$3.852	$4.063
110% of no sparks	27,791	28,531	43,191	45,847	48,355	$2.355	$3.064	$3.326	$3.531	$3.724
No sparks case	25,265	25,937	39,265	41,679	43,959	$2.140	$2.786	$3.024	$3.210	$3.386

Figure ES 2 **Benefit cost ratios with increases and decreases in patronage**



When we examine smaller sparks effects by increasing patronage (and consumer surplus) from the no sparks effect base, and decreasing them from the strong sparks effects maximum demand end-point, we find an asymmetry. The benefit cost ratio in the strong sparks effect case diminishes sharply with even small reductions in patronage, whilst we require an increase in patronage of sixty percent above the no sparks effect case level to achieve benefit cost ratios greater than zero.

The authors are agnostic about the existence or otherwise of a sparks effect associated with the NSLRS (and consider that there is insufficient evidence to predict its likely size). We note that empirical cases exist where the replacement of a bus route with a rail route have resulted in large increases in patronage, but also note that clear reasons as to why this might occur (absent of the train being faster than the bus) have not been forthcoming, or seem relatively small compared to the size of the effect.

For this reason, we do not make predictions about the likely size of any sparks effect. Rather, we suggest that a benefit cost ratio slightly in excess of one requires a strong sparks effect (roughly equal to that cited by Newman, 2011, for Perth), but that smaller sparks effects will produce much less favourable results. Overall, our conclusion is that positive social benefits for the NSLRS are a feasible outcome, but that the project carries very high risks.

Costs

The costs of the project have been estimated as being between $12.6 and $13.3 million per annum (slightly lower in the first five years when maintenance costs are smaller). This is based upon the findings of the Stage Two Report, and an adjustment of more rolling stock, which would be needed if demand is as high as the strong sparks effect implies, with the capital paid for via a loan with a real interest rate of seven percent (based on advice from the Tasmanian Department of Treasury and Finance). Further details on costs are available in the main body of the report, and considerably more detail in the Stage Two Report.

Other costs

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

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

Benefit	Description	Rating
Line closures during construction	The line, which is lightly use, would need to close during construction	Low
Road congestion effects from boom gates at intersections	There are 12 intersections between the road system and rail, and boom gate closures could adversely affect traffic as trains pass.	High
Amenity in Mawson Place	The rail may detract from heritage value in Mawson Place, particularly if overhead wires are used.	Low
Safety in Mawson Place	Pedestrians and the train would mix in Mawson Place	Low

Benefits

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

Monetised benefits

We include the following monetised benefits:

- Pollution costs and their reduction.
- Travel time savings.
- Savings in fuel and other operating costs for cars.
- The alleviation of social exclusion.
- The savings from lower accident cost risks.
- Parking costs.

Non-monetised benefits

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

Table ES 4 **Summary of non-monetised benefits**

Benefit	Description	Rating
Social costs of congestion	Chapter Two includes only the private costs, fuel savings and pollution reduction. BITRE (2007) also show savings to business. We quantify these, but believe the results are not sufficiently robust to be used in a cost benefit analysis.	Medium
Social exclusion	People are able to access services and the wider community more easily, and do not need to incur the financial burdens associated with owning a car.	Medium
Creation of TODs	There are numerous development opportunities associated with the creation of TOD precincts which improve the amenity of the region and extend beyond travel time savings.	Medium
Environmental pollution	We explore in more detail what effects might result from lower pollution, rather than just quantifying it.	Low
Tourism	We show how the NSLRS might benefit tourism.	Low

Distribution of costs and benefits

The analysis finds that there are important positive impacts of the NSLRS, from a distributional perspective. In particular, usage of the system is concentrated in areas of relatively high social exclusion. Moreover, the NSLRS, through its feeder bus services, appears to be very effective in providing greater access to the rest of the city from Bridgewater and Brighton; two relatively low socio-economic areas in the north of Hobart.

Sensitivity analysis

To undertake the sensitivity analysis, we perform a Monte Carlo simulation of benefit cost ratios. This allows us to incorporate thousands of combinations of high costs, low benefits, low costs and high benefits and so on. The results are shown in Chapter Six.

Information sources

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

Glossary

ABS	Australian Bureau of Statistics
BITRE	Bureau of Infrastructure, Transport & Regional Economics
DEC	Derwent Entertainment Centre
DED	Department of Economic Development (Tasmania)
DIER	Department of Infrastructure, Energy and Resources
HCC	Hobart City Council
MONA	Museum of Old and New Art
NSLRS	Northern Suburbs Light Rail System
OOSM	Optimal Operating Service Model
PIA	Planning Institute of Australia
SEU	Social Exclusion Unit (Office of the Prime Minister – UK)
STCA	Southern Tasmanian Councils Authority
TOD	Transit Oriented Development
TRB	Transportation Research Board (US)

1 Introduction

ACIL Tasman, Hyder Consulting and SEMF have been appointed by the Department of Infrastructure, Energy and Resources (DIER) to assess the business case for a light rail passenger system which makes use of the existing rail corridor between Hobart and Brighton. The study consists of three distinct stages:

- A background stage which describes the context and setting for the project as a whole and sets broad parameters for the remainder of the project.
- A stage which develops optimal operating service models for the light rail system.
- A stage which calculates the economic costs and benefits associated with the optimal operating service models.

A final stage of the project brings the reports for each of these stages together into a single final report.

The first stage of the project concluded that the costs of extending the rail system past Claremont would incur large costs without commensurate benefits. Thus, subsequent stages examine a Northern Suburbs Light Rail System (NSLRS) which extends from Mawson Place in Hobart to Claremont.

This report provides an overview of the third phase of the project, which incorporates a detailed demand analysis, and ascertains the net benefits of the proposed railway, taking into consideration the costs of the optimal operating service models derived in Stage Two.

The second chapter of this report details the approach taken in estimating the demand models which allow us to quantify benefits in the benefit cost calculations. The third chapter summarises key non-quantifiable benefits, which should also be considered by policymakers when assessing the railway. The fourth chapter provides an overview of the costs used in the modelling for this report. Considerably more detail on these costs and their derivation is contained in the Stage Two report, available from (www.transport.tas.gov.au/miscellaneous/northern_suburbs_to_hobart_cbd_light_rail_business_case). Chapter Five presents the cost benefit analysis and its results, and Chapter Six provides the sensitivity analysis around the cost benefit analysis. Chapter Seven concludes. An appendix provides details on the model.

2 Demand Model and Quantifiable Benefits

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) and producer surplus. Technically, the consumer (producer) surplus is the area between the demand (supply) 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. Producers who can produce for less than the prevailing market price also receive a benefit.

By way of a simple example, consider a consumer who would have paid $15 for a bottle of wine, but finds it for sale in a bottle-shop for only $10. The consumer receives a benefit of $5 from being able to buy the wine for less than she would have been preferred to pay. The overall benefit to society of the wine (or in this case, the NSLRS) is the sum of the benefits that consumers receive because the wine costs less than they would have been willing to pay. The actual price paid is not relevant, as this is just a transfer between two parties; the purchaser and the bottle-shop owner.

In the case of the NSLRS, the basic service being provided both before and after the NSLRS is built is transport in the Northern Suburbs of Hobart. Prior to its construction, it is transport by car and bus, and subsequent to its construction it is transport by car, bus and train.[1] The measure of the extra benefit the NSLRS brings to Hobart is therefore the change in consumer surplus which is brought about due to its construction, as people add it to the mix of trip modes they utilise. Importantly, our modelling framework includes not only the increase in consumer surplus directly associated with the NSLRS itself, but rather how all transport-related consumer surpluses change.

The distinction between the case of the competitive wine market and the NSLRS is shown in Box One.

1 We exclude walking from our model as the reasons people walk are not (usually) associated with minimising the time and money costs of travel. Implicitly, we assume incentives to walk (except to the train or bus) are unaltered by the introduction of the NSLRS

Box 1 **Consumer and producer surplus**

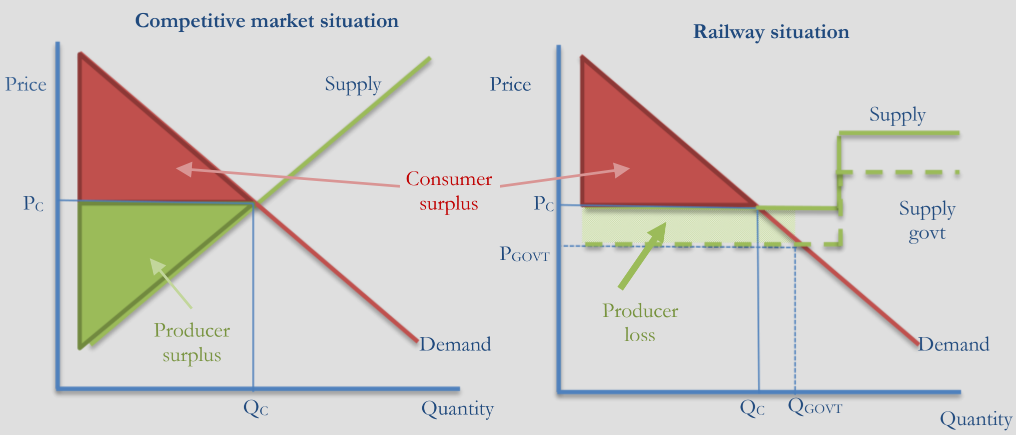
The situation of the wine shop discussed in the text above is shown in the left-hand side of Figure 1. A firm produces (in a competitive market), the quantity Q_C, which it sells for the price P_C, generating the red consumer and green producer surplus.

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. The cost of supply jumps when the railway needs to employ new plant; say a new train. The railway provider will provide a service (just like any other monopolist), which equates its marginal cost (or supply curve) with the market marginal revenue (or demand) curve. It will not earn a producer surplus (though it will earn monopoly profit where such profits are available). This is shown by the intersection between the demand and supply curves in the figure on the right of Figure 1, at the same level of output Q_C.

However, 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.

Just as in the left-hand side of Figure 1, 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 1 **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 consumer surplus, we firstly need demand curves. Detail on the formation of the demand curves is provided in an appendix, and an overview is provided below. We develop a model of trip cost, which incorporates all the cash and non-cash costs of making a trip by a given mode from a given location. Within this model, several of the parameters in each cost function can vary, and we choose different combinations of model parameters to find out which mode is the least-cost way of making a trip from each location under a given set of parameters. We then collect all these point estimates (roughly 500,000 per demand curve), and fit a demand curve through them for each of the modes, in each of the relevant situations. We then calculate the area under the demand curve at the prevailing (average) resource cost for the mode in question to provide the consumer surplus. Thus the sum of the consumer surpluses after the introduction of the NSLRS is then subtracted from the sum of the consumer surpluses prior to its introduction.

The process outlined above is repeated twice, once to include a very strong "sparks effect", and once to exclude such an effect.[2] We also examine a series of cases of weaker sparks effects to see how robust the strong sparks effect case is in terms of the benefit cost analysis.

Box 2 **The "sparks" effect**

One aspect of railways in relation to other forms of public transport has been referred to colloquially as the "sparks effect"; empirically, people are more likely to ride on a train than a bus which follows a similar route. Newman (2011) illustrates this starkly; when a train replaced the buses which had formerly run down the centre of Perth's Kwinana Freeway, patronage went from 14,000 per day on the buses to 55,000 on the trains.

There are many possible reasons for this effect, including aesthetic preferences and greater route certainty. How each affects demand is unclear, but what is clear is that a model which captures only movement from bus to rail is likely to under-estimate likely rail patronage when a new railway system is introduced. For this reason, we calibrate our model to include a strong sparks effect similar to that observed by Newman (2011).

We are agnostic about sparks effects; noting that they are an empirical observation in a number of cities, but not one whose causes are easily explained. This means it is difficult to objectively predict whether it will arise in Hobart; whether the NSLRS will improve the "public transport culture" to the extent that modal shares equal of best practice cities in Australia. It is for this reason that we also explore a model where no sparks effect exists (the other end of the demand spectrum) and intermediate cases.

Before providing further detail on the model, it is worth expanding on what we mean by "resource cost". Rather than use the cash price (say the ticket price

[2] The "sparks effect" is proxied by tailoring the model to give modal share outcomes for rail which are roughly the same as in best practice systems around Australia, resulting in an increase in patronage roughly the same as Newman (2011) notes for Perth. Since the largest component of our resource cost is the cost of travel time, the model is tailored to produce a sparks effect by increasing train speed (to ten percent above the speed of cars in free-flow traffic) in order to reduce travel times.

for buses) alone, we include all of the costs of travel, including travelling time, waiting time, emissions produced, accident risks and any benefits associated with overcoming social exclusion. This is more robust than adding these externalities later in an ad-hoc fashion, because they directly influence the choices that consumers make.

2.1 Overview of the model

The demand model is based upon a notion of minimising the total resource cost of making a given trip. We divide the types of trips made into two:

1. Directed trips to work and school. We assume two of these are made per day (one to work and one home) and that consumers simply minimise the cost of making each trip.
2. Undirected trips, which cover all other forms of travel and have a constant length, rather than a constant number of trips per day. The number of trips undertaken is found by examining when the cost of the marginal trip matches its marginal utility. The cost minimisation maxim still holds.

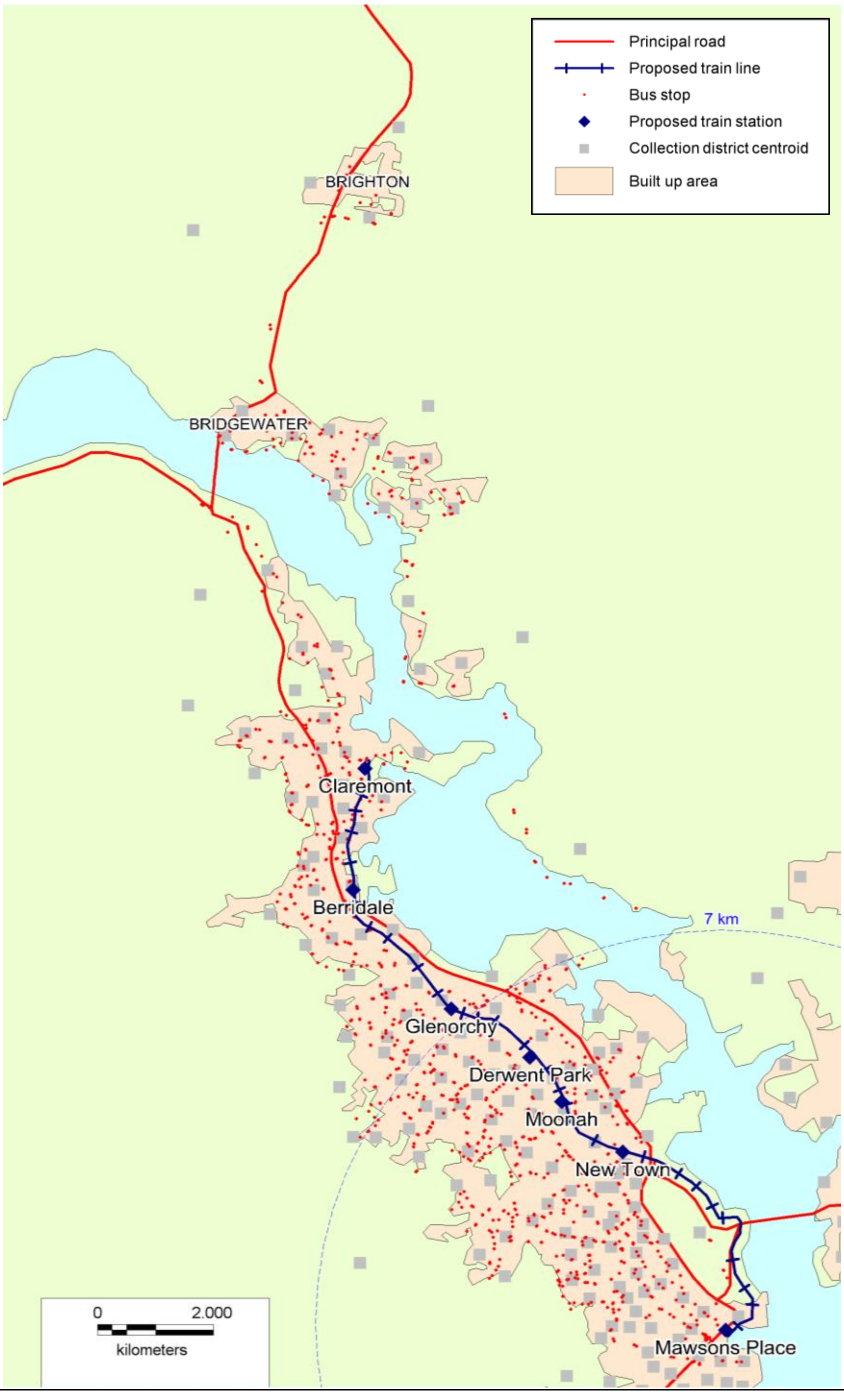
The model has a spatial element in it for both kinds of trips; for directed trips there is an origin and a destination (both set exogenously). For undirected trips, the location of the representative consumer determines which modes are available at lowest cost to her. The locational element of the model is obtained by assuming that representative consumers reside in one of 204 Census Collection districts in Northern Suburbs of Hobart, and that they travel in a directed or an undirected manner from these locations. Figure 2 provides an overview of the Census collection districts we utilise.

The cost benefit analysis requires the calculation of benefits in each year. We do not calculate demand curves in each year, but rather do so three times, and then use the change in population to map the growth of the change in consumer surplus. The first estimation of demand curves occurs prior to the introduction of the NSLRS, and provides the base consumer surplus calculation. We then estimate the consumer surplus immediately following the introduction of the NSLRS. In so doing, we assume that the bus system "reacts" by removing competing bus services, and re-allocating resources to feeder-buses such that the bus system is cost neutral in respect of the introduction of the NSLRS.[3] The specific bus route assumptions are shown in Figure 3.

---

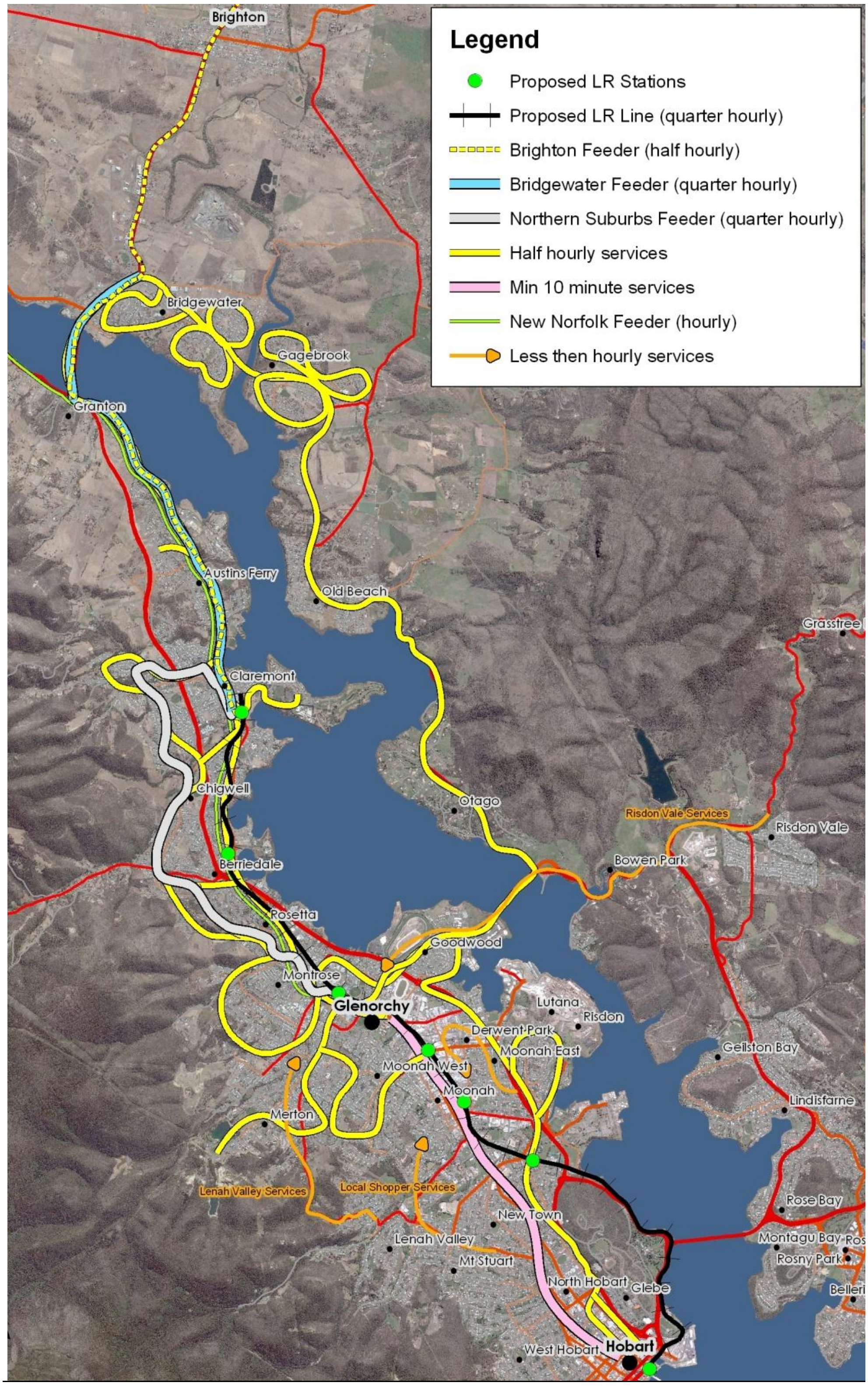
[3] DIER undertook this analysis, choosing which competing bus services to remove, and how to change the frequency of feeder bus services so that the net effect on the costs of the bus operator is zero. We are grateful for this valuable input.

Figure 2 **Northern Corridor, population and transport infrastructure**



Data source: ACIL Tasman map of ABS, DIER and Geoscience Australia data

Figure 3 **Conceptual Feeder bus routes associated with the NSLRS**



Source: DIER

The final set of demand curves is calculated for the period after Hobart has "reacted" to the introduction of the NSLRS by changing residential density to make best use of the new transport option. Specifically, we assume that after five years, four new Transit Oriented Development (TOD) precincts (each consisting of two Census collection districts to make them roughly comparable in size to Subiaco in WA) are developed at Derwent Park, Moonah, Glenorchy and Claremont.[4] We assume that residential density in each of these collection districts grows to equal that of Subiaco, and that it falls commensurately (taking account of population growth) in the remainder of the Glenorchy Local Government Area. This "TOD Effect" means that patronage of the NSLRS rises substantially as residents make use of it for travel.

In our model, there are (up to) five possible trips a person can make, and thus (up to) ten possible demand curves for a given time period, since we have directed and non-directed travel. The five possible trips are:

- Drive a car.
- Walk to the bus stop and catch a bus.
- Walk to a train station and catch a train.
- Walk to a bus stop and catch a feeder bus before catching a train.[5]
- Drive to a train station and catch a train via park 'n ride.[6]

We assume in our analysis that feeder bus timetables match the NSLRS timetable perfectly at every NSLRS station (rather than just at the bus interchanges) so there is zero waiting time between bus and train at each station. Also, since we do not have data on where in Hobart City people are likely to work, we do not have a walk leg at the termination of directed trips from home for any of the modes shown.

Prior to the development of the NSLRS, only the first two options are possible, and there are thus four demand curves to derive and four consumer surpluses to calculate. Subsequent to its development, all five modes are possible, and there are thus ten demand curves and ten consumer surpluses. The sum of the four initial consumer surpluses are subtracted from the sum of

---

[4] The part of Subiaco which is characterised by TOD development is roughly one square kilometre in size. We acknowledge that a period of five years for land zoned to create a TOD to become a fully-functioning TOD is an optimistic assumption.

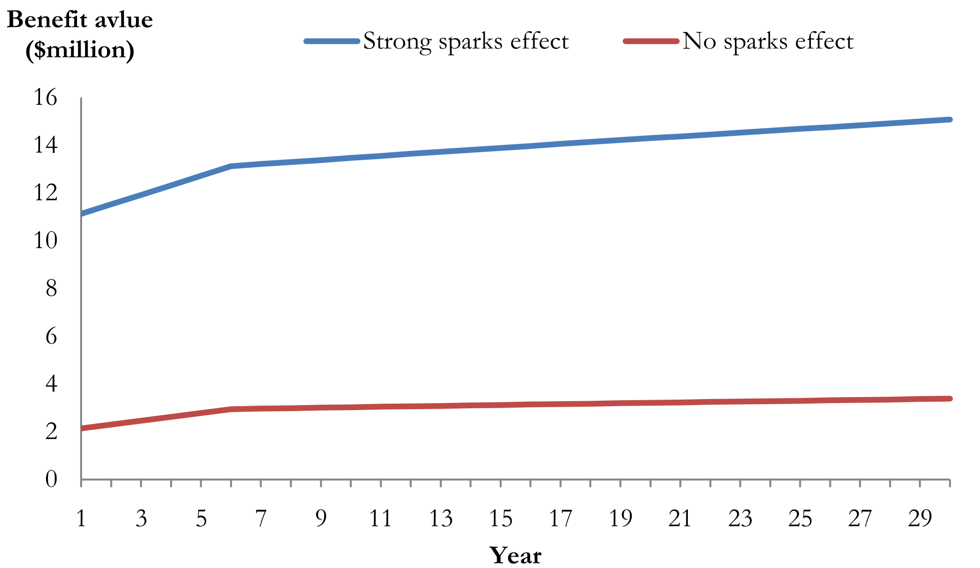
[5] We assume in our analysis that feeder bus timetables match the NSLRS timetable perfectly at every NSLRS station (rather than just at the bus interchanges) so there is zero waiting time between bus and train.

[6] We do not explicitly include kiss 'n ride trips because it is difficult to distinguish in the model between people who drive to a train station and those who are driven to the train station. However, we do allow for many more park n' ride stations than was assumed in the Stage One Report, and we allow these to exist at every station.

the ten subsequent consumer surpluses to obtain the change in consumer surplus, which is then used as the benefit component of the cost benefit analysis in Chapter Five. This is done twice to account for the "pre-reaction" period of five years before TODs are fully developed, and again for the period when TODs have been fully developed.

Figure 4 shows the results in terms of consumer surplus in the case where a strong sparks effect prevails, and where no sparks effect prevails. The results are clearly very different, with the latter being roughly a fifth of the former. This is because, unless a strong sparks effect prevails, the inherent incentives to switch modes are not great, due primarily to the relatively low levels of congestion on Hobart roads.

Figure 4 **Annual consumer surplus values**



A second point is worth making. The development of the NSLRS, as it appears in the model, does not involve just the creation of a rail link, but also the improvement of bus services in the Northern suburbs of Hobart. Without the strong sparks effect, much of the benefit is actually people using the more frequent buses. We have not explored the costs of changing the bus system to increase frequency in the Northern Suburbs of Hobart, but we suspect this might have a large benefit-cost ratio in its own right.

The above is a very brief overview of the process followed. Further detail is provided in an appendix. We now turn to the non-quantifiable benefits associated with the development of the NSLRS

3 Non-Quantifiable Benefits

The discussion in the previous chapter examines the benefits we have been able to quantify robustly in our analysis. In this chapter, we focus on non-quantifiable benefits, which are important for consideration of the NSLRS on the part of policymakers. We focus in particular on four key benefits:

- The social benefits of congestion alleviation.
- Impacts on socially disadvantaged people (above and beyond how their travel is impacted as discussed in the previous chapter.
- Benefits associated with the creation of TOD areas, above and beyond the benefits to those living in these areas who are able to access a light rail service (as outlined in the previous chapter).
- Environmental pollution benefits that go beyond the small carbon effect calculated in the previous chapter.
- Tourism benefits.

There are some benefits suggested in the original request for tender which we have considered, but not included. These are:

- Employment effects associated with the NSLRS.
- Changes in property values.
- Improvements to public transport viability.

The employment effects of the NSLRS are likely to be very small. Even in the construction phase, the track alteration required is not likely to add significant numbers of new jobs to the economy, and may indeed be undertaken by existing TasRail staff or their contractors. Once operational, the railway is likely to employ approximately 15 people.

In relation to property values, these do tend to rise when TODs are created, but housing quality in the relevant area also increases, so it is not clear how one should properly attribute increases in value. Moreover, while increases in property prices might advantage those already living in the area, the wider benefits are uncertain; everyone trying to buy into the area faces higher prices, and some (first home buyers and those on low incomes) may find themselves excluded from an area which was formerly attractive to them.

Likewise, effects on public transport viability may be small, or even negative. To the extent that the increased patronage on feeder buses allows the bus operator to realise economies of scale (more people on the same number of buses), then the bus service may become more viable. However, to the extent that this does not occur, or to which it is overshadowed by larger numbers of concession holders using the service, the bus system may in fact become more costly for government.

3.1 Social benefits of congestion alleviation

One important effect of the NSLRS is its effect on congestion. The Bureau of Infrastructure, Transport and Regional Economics (BITRE, 2007) suggests that the costs of congestion may reach $70 million per annum in Hobart by 2020, and that they consist of:

- Private costs associated with extra travel time and travel time variability.
- Business costs associated with extra travel time and travel time variability.
- Increased vehicle operating costs (particularly fuel consumption).
- Poorer air quality.

The modelling in Chapter Two incorporates all of these factors into the consumer choice model through explicit prices with the exception of business costs. BITRE (2007, p130) suggests that business costs may reach $24 million per annum in Hobart as a whole by 2020.

The key issue, then, is the proportion of these business costs that can be associated with the Northern Suburbs of Hobart, as congestion occurs in other parts of Hobart as well. We do not have robust data on how much of the total congestion in Hobart can be attributed to certain regions within Hobart. However, we can provide some, very rough, boundary analyses.

If we consider all trips in the Local Government Areas of Hobart and Glenorchy that are either between these two jurisdictions or within each one, and all trips from Brighton to Glenorchy or Hobart, then (according to DIER, 2010) roughly 42 percent of trips in Hobart contribute to congestion which might be alleviated by the NSLRS. However, few of the roads in these Local Government Areas are congested. If we focus just on the Brooker Highway, (the most congested of the road in the study area and its major route for commuters), and just on vehicles which use it during peak periods when congestion occurs, then roughly 8.5 percent of trips in Hobart contribute to congestion which might be alleviated by the NSLRS.

The strong sparks effect version of the model predicts a reduction in cars on the road (in the Northern Suburbs of Hobart) of ten percent once the NSLRS is developed. This means a reduction in congestion costs of between 0.85 and 4.2 percent of the total calculated for Hobart by BITRE, or between $206,000 and $1 million per annum.

The underlying assumptions of the BITRE (2007) model and our own detailed in Chapter Two are not identical. Moreover, the calculation of the contribution to overall congestion outlined above is very rough, and subject to wide error bands.[7] We thus do not include the numbers in the cost-benefit analysis, because we do not consider them to be sufficiently robust.

3.2 Benefits in terms of social disadvantage

As noted in the Stage One Report, the NSLRS will traverse several areas of social disadvantage, and through its feeder bus network, will significantly improve the frequency of public transport links as far north as Brighton.

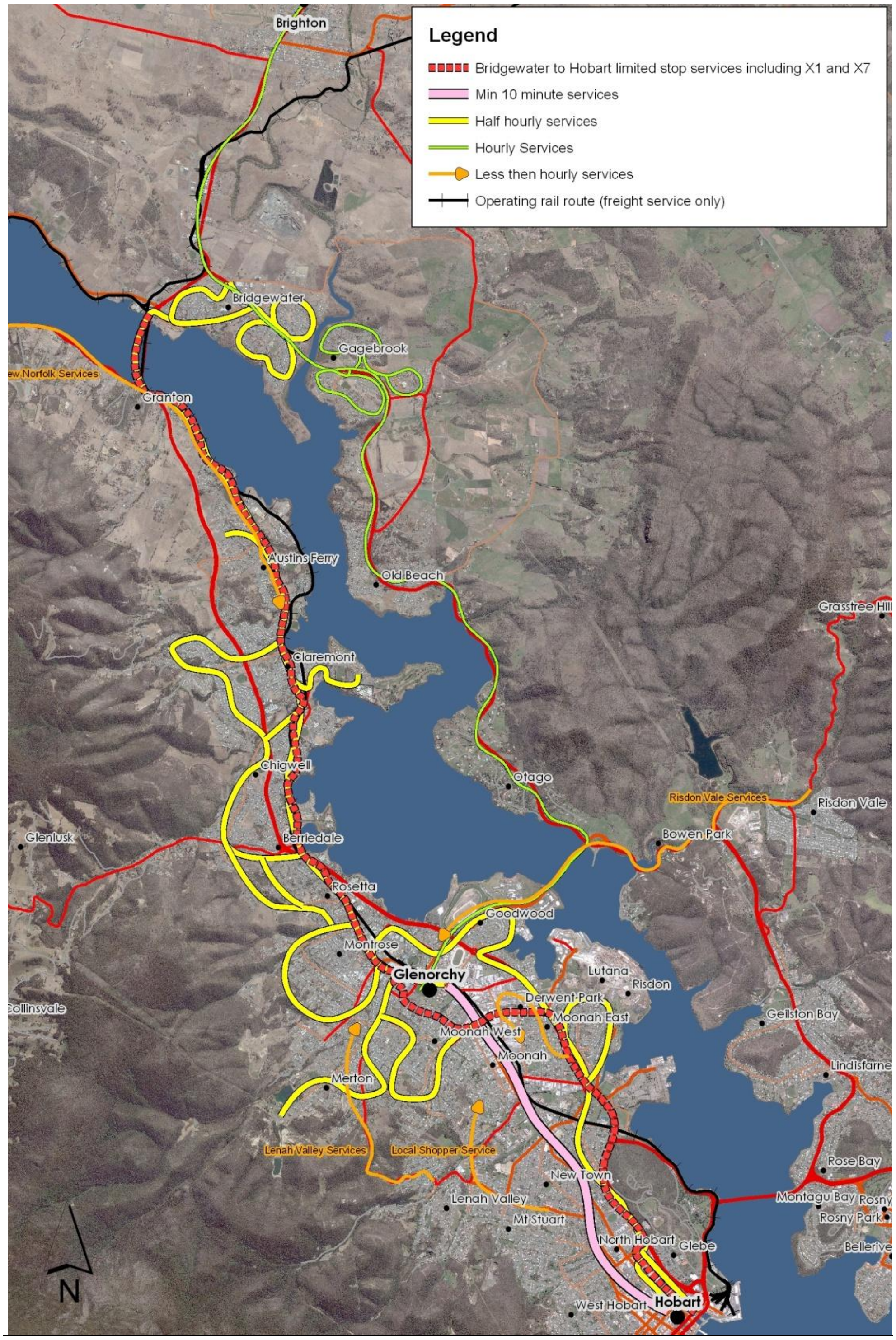
Currie, Greene, Hensher, Stanley, Stanley, & Vella-Brodrick, (2010, p1) note that 'measures to reduce transport disadvantage are thought likely to improve the prospects for social inclusion'. DIER (2009, p66) notes that 'people with a disability and the aged are vulnerable because they face particular problems in reaching appropriate services and facilities and their need to access these services is likely to be higher'. Hurni (2010, p1) also notes, drawing upon SEU (2003), that 'international studies provide evidence that a lack of suitable and affordable public transport can be a significant barrier to participation in work and education and access to health services, shopping and social, cultural and recreational activities for socially disadvantaged groups of people'. Therefore, if it is accepted that greater access to high quality public transport may enhance social inclusion, then the provision of a new light rail service between Claremont and Hobart along with the proposed feeder buses (see Figure 3) which would extend frequent services to Brighton and Bridgewater, should be considered likely to help reduce social disadvantage.[8]

Public transport (in the form of buses) is available to the suburbs in North Hobart, but services, particularly those north of Glenorchy, are not frequent. This is shown in Figure 5, which shows current service frequencies in the study area. It should be compared with Figure 3 in Chapter Two, which shows the situation after the NSLRS has been developed.

7 It is not clear that more exact data are available which might improve these estimates.

8 As would similar high quality services that did not necessarily involve rail (sparks effects notwithstanding) but involved a good feeder-bus system; it is the quality, rather than the mode, which matters in the reduction of social disadvantage.

Figure 5 **Conceptual Current bus routes and timetables**



Source: DIER

Where public transport options are poor, people have little option but to purchase a car. A car represents a fixed investment,[9] and can thus represent a substantial burden on those with low incomes. Therefore, a lack of good public transport options may be contributing to costly car ownership and maintenance and hence social exclusion and disadvantage; the converse being that the provision of a light rail service may help reduce social disadvantage by decreasing household reliance and expenditure on cars as their primary means of transport.

The provision of a faster, more reliable, and regular light rail system and its feeder buses will enhance access and availability to more publicly acceptable public transport options. The SEU (2003, p11) report notes that people in the United Kingdom are reluctant to travel long journey times or distances; 'the average distance to work for people on low incomes is three miles compared with eight for the general population'. The report goes on to state that 'jobseekers are typically not prepared to travel more than thirty minutes to work'. The lack of fast and regular forms of public transport may deter unemployed people from looking for work outside a certain radius. The NSLRS will allow people from Bridgewater and Brighton to travel much more rapidly to Central Hobart (using feeder buses and trains) than is possible at present given infrequent, long services, and this is likely to considerably improve their ability to access work and social opportunities. Enhanced public transport options will also improve access to health services, to learning, to food shops and to social, cultural and sporting activities.

3.3 Benefits from the creation of transit oriented development

In Chapter Two, we explored the benefits of TODs through their effect on patronage of the NSLRS. However, they provide much wider benefits than this, provided they are well designed. We explore some of these benefits here, and also outline some of the planning and other decisions which can assist in ensuring that TODs achieve these benefits.

TODs contain specific features designed to encourage public transport use and reduce urban sprawl. Examples of these features include mixed-use developments (residential, commercial, retail) that will use public transport at all times of day, excellent pedestrian facilities such as high quality pedestrian crossings, narrow streets, and reduction of building density as the buildings become more distant from the public transport node. TODs generally promote the use of public transport systems and reduce reliance on cars by putting

---

9 That is, it costs money whether it is driven or not. A bus or train does not have this characteristic for a householder.

public transport in the heart of the development. Standard modes of development are often based around transit mechanisms located on the periphery and separate to commercial, residential and industrial areas.

Benefits of TOD

The potential benefits of TODs are wide ranging and may span social, environmental, and fiscal concerns. Focusing growth around transit stations capitalises on expensive public investments in transit by producing local and regional benefits. TODs can be an effective tool in curbing sprawl, reducing traffic congestion, and expanding housing choices.

The most direct benefit of TODs are increased public transport use, which we capture in the demand model. Research shows that residents living near stations are five to six times more likely to commute via transit than are other residents in other locations (TRB, 2004) who typically have very low use of public transport.

Other primary benefits include the revitalisation of neighbourhoods, financial gains for joint development opportunities, increases in the supply of affordable housing, and profits to those who own land and businesses near transit stops. Among TOD's secondary benefits are congestion relief, land conservation, reduced outlays for roads, and improved safety for pedestrians and cyclists.

Planning for TODs

In order to achieve these benefits, a TOD needs to be both well-planned and be able to attract sufficient demand from those wishing to move there. Newman (2007) describes four strategic planning tools for TODs applicable to the NSLRS:

- A strategic policy framework that asserts where centres need to occur and at what kind of density and mix.
- A strategic policy framework that links centres with a rapid transit base;
- A statutory planning base that requires development to occur at the necessary density and design in each centre, preferably facilitated by a specialist agency.
- A public-private funding mechanism that enables the transit to be built or refurbished through a linkage to the centres if will service.

By implication, therefore, the provision of a transit will in itself not necessarily result in TODs. Other State and local policy and planning factors as listed above will be critical in order for such TODs to occur. From this perspective, the assumption in Chapter Two that TODs will be created within five years of the development of the NSLRS may be optimistic, particularly if planning decisions around TODs do not start before the NSLRS is developed.

The concept of rapid transport which could involve light rail or exclusive bus corridors linking Hobart with the northern suburbs has been supported in a number of local and State planning documents (HCC, 2009; PIA, 2008; DIER, 2010; STCA, 2010). However, a statutory planning mechanism will be needed to drive the successful renewal of areas associated with the light rail. This will need to include clear zoning and design mechanisms to facilitate the development of TODs along the light rail route.

Strategic planning policy is currently being reviewed through the implementation of a state-wide planning scheme template and the preparation of regional planning strategies. This provides a good opportunity for long term implementation of urban density and renewal strategies.

For the purposes of modelling demand, we have considered four sites suitable for TODs; at Derwent Park, Moonah, Glenorchy and Claremont stations. A more detailed study would be required to determine precise locations and design of each TOD.

The relocation of Hobart's main industrial transport hub to Brighton may draw some industrial activities away from the Glenorchy area in the longer term (STCA, 2011). DED (2008) also notes that small scale industries might be pushed out of inner city locations to allow retail and services to expand. The placement of the light rail stations in combination with this trend may facilitate TODs over time. The potential for redevelopment of existing warehousing and industrial buildings in these areas could potentially provide an opportunity for density increases and urban renewal. Renewal of previous industrial inner city areas in Melbourne, Sydney and Perth has led to the development of higher density warehouse style residential and commercial precincts that retain an element of their original character.

Future Requirements for Consideration

TODs will not necessarily develop of their own accord simply due to the provision of a public transport system, even one that is superior to an existing transport system. Planning and marketing measures will need to be considered in order for transit oriented developments to become a reality. These include:

- A master developer approach to station area development might enable the correct mix of residential and commercial development in a form and scale appropriate to the local areas.
- Supportive land-use designations, which are rated as the most important factor amongst potential TOD developers (TRB, 2004).
- Planning concepts need to be firm but adaptive to allow development and change within TODs over a potentially long timeframe. This is particularly important in Tasmania where the population is not expected to increase

significantly in the short-term. Planning mechanisms will need to incorporate staged development along the light rail line and may need to include several generations of development before a mature TOD is realised.

- Rationalisation of parking policies in relation to TOD is an important consideration. Parking can form a large obstacle to TOD and separating a station from the neighbouring community with a large car park can diminish the quality of the walking environment. Similarly, walking access and quality of circulation and the overall pedestrian environment are critical to successful TODs. Research has shown that the proportion of people who will walk to the station decreases markedly if there are significant physical barriers or psychological barriers like wide, busy roads and incomplete foot-path networks (TRB, 2004).
- The provision of park-and-ride may conflict with day time uses and local residents, particularly if large numbers of 'outsiders' park during daylight hours. Solutions might include siting parking more peripherally to a station or away from a community and toward an active highway corridor (for example closer to the Brooker Highway than to Main Road).
- Where affordable housing is being built near stops, reduced parking quotas or flexible planning standards should be considered to reflect the tendency of many TOD households to own fewer cars.
- Larger transit stations may need to accommodate buses, park-and-ride, pedestrians, cyclists, passenger drop off, taxis, goods delivery, and other access functions. Movement conflicts, circuitous travel paths, and suboptimal usage of space are likely (TRB, 2004). Particular thought will be required to create a comfortable human-scale environment that is functional as well as complimenting the existing or desired neighbourhood character.

3.4 Environmental pollution benefits

The SEU report (2003, p14) notes that 'road traffic emissions make a significant contribution to levels of air pollution, particularly in towns and cities. Pollution from traffic fumes can exacerbate the symptoms of some people who may already suffer from breathing difficulties or respiratory diseases such as asthma'.

Lucas et al (2001, p5) note that pollutants present in vehicle emissions include 'carbon monoxide, oxides of nitrogen, sulphur dioxide, hydrocarbons and airborne particulates'. 'Particulates are.….linked with asthma and lung cancer in human beings'. 'Oxides of nitrogen and hydrocarbons.… produce photochemical smog (which) reacts to create ozone…which damages …the lining of people's lungs'.

The SEU report (2003) notes that disadvantaged communities suffer disproportionately from pollution due to living near busy roads. This is supported by other studies referenced in Lucas et al (2001) which note that minority and low-income groups live in higher-trafficked areas than others and are exposed to higher levels of transportation pollutants that lead to health problems.

Assuming a significant reduction in the use of cars due to the introduction of a light rail system, this is likely to reduce particulate and photochemical smog pollution generated by cars. This in turn is likely to particularly benefit communities that live adjacent to busy roads which tend to be disadvantaged communities.

3.5 Tourism benefits

Along the route of the NSLRS are a number of key tourism and "event" locations. Not only does the NSLRS make these locations more accessible (particularly for people who do not drive, and for visitors to Hobart who are unlikely to have a car and for whom the bus system is confusing), but its presence also improves the viability of these locations in their own right by making them more accessible.

We discuss the consequences of the NSLRS for some of these major tourism attractors below.

MONA / Moorilla Winery

The recently opened Museum of Old and New Art (MONA) is located in the Morilla Winery, Berridale (approximately 500 metres from the proposed light rail station). The complex includes restaurants, bars, MONA, and The Pavilions accommodation. MONA has drawn local and interstate visitors with its collection of antiquities and controversial, contemporary art and 'wunderkammer' approach to exhibiting these artworks. By April 2011, 150,000 people had attended the museum since its opening in January.

MONA is also used as the venue for music events that are staged as part of the annual Hobart MONA FOMA festival. These events have included the mostly free staging of international music events. The 2011 MONA FOMA attracted 30,000 people, although a large number of these would have attended events staged at the Princes Wharf near Salamanca, Hobart.

Public transport access from Hobart is currently provided to MONA by means of a ferry ($15 return) travelling between the wharves in Hobart and the museum as well as Metro bus services. The proximity of the Intercity Cycleway also means that that cycling is an important means of access. However, the location of the proposed Berridale station adjacent to MONA provides a second option for visitors. This is particularly useful because the trains operate more frequently than the ferries, improving accessibility.

Claremont Golf Club Redevelopment

The Claremont Golf Club is currently in the planning stages with respect to a proposed development on the Cadbury Estate. This multi-million dollar Claremont Peninsula Sports Complex development will encompass the existing Claremont Golf and Bowls Club (approximately 500 metres from the proposed light rail station) and will provide new and improved sporting facilities for all existing members of both the Bowls and Golf Clubs, as well as providing accommodation and sporting facilities for the many thousands of visitors to the northern suburbs, including those who visit the Cadbury factory and MONA at the Moorilla Winery, located in nearby Berriedale. Specifically, the development includes the construction of a 64 unit Active Retirement Community, incorporating 2 and 3 bedroom dwellings, as well as a 75 room hotel complex which is currently proposed to be joined to, and form part of, the existing clubhouse.

The location of the railway near the development means that visitors and residents can easily use the facility as a base and travel into Hobart to visit its attractions. This improves the attractiveness and thus the viability of this facility.

Royal Hobart Show Grounds

The Royal Hobart Showgrounds located near Glenorchy (approximately 1km walking distance from the proposed light rail station) is used for a number of events throughout the year including the Royal Hobart Show, regular Sunday morning Showgrounds market the Royal Hobart International Wine show, the second largest wine show in Australia, the Royal Hobart Fine Food Awards, the Tasmanian Vineyard of the Year Competitions. The Royal Hobart Show was attended by 46,400 people in 2009.

The location of a station nearby the showgrounds makes the venue more attractive, not only for its current uses, but also potentially for future uses. In Perth, special event stations on the Fremantle and Armadale lines are located adjacent to similar showgrounds, adding to their attractiveness.

Other facilities

Some other facilities along the line which might also benefit from the NSLRS include:

- **Derwent Entertainment Centre (DEC):** The DEC is located on the waterfront near Glenorchy (approximately one km from the proposed light rail station) and is regarded as the premier entertainment venue in the state. The DEC's capacity is up to 5,400 fully seated and 7,500 for general admission and is regularly used for concerts, conventions, exhibitions, dinners, trade shows and meetings.
- **Cadbury Visitors Centre:** The Cadbury Visitor Centre is located at Claremont (approximately 0.8 km from the proposed light rail station by foot) and is one of the most popular tourist destinations in southern Tasmania.
- **Elwick Racecourse:** The Elwick Racecourse is located on Goodwood Road, Glenorchy (approximately 1.5km from the proposed light rail station by foot) and hosts a number of different racing events throughout the year including the Hobart Cup.
- **Glenorchy Arts and Sculpture Park:** along the Elwick Bay foreshore could be considered as an attraction.

Tourism Impact of Light Rail Proposal

The provision of a light rail system leaving from the centre of Hobart would enhance tourist access to key tourist attractions (detailed above) to the north of Hobart. The use of heritage trams would make the journey attractive in its own right as a tourist activity.

Issues such as connectedness to, and provision of, pleasant pedestrian walkways that would link proposed light rail stations with existing tourist attractions may need further development to ensure that the 0.5 to 1km walk between stations and sites is not a deterrent to using rail. Currently, most of the pedestrian routes to the listed attractions are indirect routes that run along and across busy roadways, potentially detracting from the overall tourist experience. The provision of shuttle buses by the tourist attraction companies and provision of appropriate bus parking at the station would also assist the use of light rail to access the above-mentioned attractions.

Cycle paths are provided along the length of the rail line and these could provide a strong link to tourist attractions. Bicycle hire facilities near the stations may also encourage tourists to use light rail and then bike-paths or roads to access the attractions. Again, connectedness between the rail stations and the bike paths and the tourist attractions needs to be developed for this to occur effectively.

In summary, the provision of the light rail system would improve the public transport options available to tourists to access tourist attractions in the northern suburbs.

4 Costs

This chapter provides an overview of the cost assumptions as they are used in the benefit cost analysis in the following chapter. These cost assumptions are based, in turn, on the modelling undertaken in the Stage Two Report undertaken by Hyder Consulting.

4.1 Monetised costs

Hyder derived two Optimal Operating Service Models (OOSMs) which are identical in terms of their track and station infrastructure, but differ in their use of diesel or electric vehicles. The costs associated with these models are summarised in Table 1

Table 1 **Cost parameters from Stage Two Report ($'000)**

Cost Item	OOSM 1 (Diesel)	OOSM 2 (Electric)
Track	$33,544	$45,044 (incl $11,500 for electrification)
Structure	$3,200	$3,200
Stops (incl terminus)	$3,989.7	$3,989.7
Urban design & landscaping	$203.669	$261.169
Project management	$2,046.9	$2,624.8
Design	$1,842.2	$2,362.3
Rolling stock (5 units)	$25,000	$25,000
Contingencies	$9,745.293	$9,745.293
Total capital expenditure	$79,571.762	$92,227.262
Maintenance – 1st five yrs	$163 pa	$313 pa
Maintenance – thereafter	$2,400 pa	$2,400 pa
Operating costs	$2,750 pa	$2,500 pa

Data source: Hyder Stage Two Report

The demand forecasts for the strong sparks effect case imply peak-hour travel of between 4000 and 6000 people.[10] Advice from Hyder suggests that the larger of the rail vehicles examined are able to carry 300 people.[11] Assuming that journeys to work cover a three hour period (6-9am, for example) and assuming 80 percent of the traffic is in one direction (towards Hobart in the mornings and away from Hobart in the afternoons), Hobart would require two more rail vehicles and two more drivers than outlined in the Stage Two Report. We have assumed that these costs (a lump sum of $10 million and $200,000

[10] In the no sparks effect case, demand is much lower, and four rail vehicles more than adequate, and thus the costs in Table 1 are used, with no additional rail cars or drivers.

[11] Others carry 200 people, which would require more rail cars. Hence we are using a conservative cost assumption here.

per annum respectively) are the only costs associated with having more rail vehicles on the track, which is a conservative assumption.

In order to estimate relevant costs for the benefit cost analysis, we assume, as in the Stage One Report, that the capital funds are borrowed at the Tasmanian Department of Treasury and Finance rate of seven percent and repaid over a period of 30 years. This gives rise to an annuity, to which annual operating and maintenance costs are added, to obtain the amount of funding which needs to be recovered from revenues, or paid through government subsidies, per annum.

Under OOSM 1, (Diesel vehicles) the annual costs (capital plus operating) are $10.3 million per annum for the first five years, and $12.6 million per annum for the remainder of the project life. Under OOSM 2, (Electrified vehicles) which has higher capital costs, the relevant figures are $11.2 and $13.3 million respectively. If the extension of the line to Elizabeth Street outlined in the Stage Two report were added, at a cost of $2.5 million, it would add around $200,000 per annum to these costs.

We also assume that the cost of providing the subsidies is 20 percent more than the cost of the subsidies itself. Collection of taxation revenues places an "excess burden" on the economy (through efficiency losses due to government handling of funds and allocative efficiency losses in the wider economy) which varies according to the type of tax imposed (see KPMG, 2010). The figure of 20 percent is a rough weighted average of the excess burden of state taxes, and is likely to be conservative.

4.2 Non-monetised costs

There are a number of costs which might also be associated with the development of the NSLRS which are difficult to quantify robustly, but which need to be considered by policymakers in their decisions.

During the period of construction, the line is likely to become unavailable for other users. This extends also to the cycle path which runs along-side it, although it is likely to be less adversely affected. At present, freight trains operate along the line. However, a new freight hub is being developed in Brighton; indeed this is the impetus for the development of the NSLRS. Thus, although some freight trains might be prevented from using the line, the incidence is likely to be rare, and the costs consequently small.

While the NSLRS is in operation, it is likely to have an impact on surrounding traffic through the 12 intersections between the track and the surrounding road network which are not grade separated. At present, the road system is barely affected by rail, because the number of freight trains is small. However, once the NSLRS is developed, several trains per hour (each way) will traverse the track, and may result in delays to surrounding traffic, particularly where the track intersects with busier roads. An examination of the detailed impacts of the NSLRS on the surrounding transport system is beyond the scope of this report. However, such an investigation will clearly have to be conducted before the NSLRS is developed.

The NSLRS is intended to terminate in Mawson Place, passing through the existing rail yards as it does so. Although it may improve re-development opportunities in the existing rail yard,[12] it may adversely affect tourism and heritage value in Mawson Place itself. This is especially the case if overhead wires are used, and indeed the Hobart City Council faced considerable opposition[13] (subsequently overcome) to its proposal for light rail with overhead catenary wires in Mawson Place. There may also be safety concerns mixing light rail with pedestrians directly adjacent to a major road.

Although these concerns exist, it is worth noting that many European cities (and Melbourne with its trams) have light rail systems in their hearts which mix with pedestrians without adversely affecting either tourism and heritage amenity or public safety. It is therefore by no means a foregone conclusion that these adverse consequences will eventuate. It may be a case that a period of adaptation is required, and that costs might exist initially, but dissipate as the city becomes accustomed to its light rail system.

12 There are various plans at present, including a residential development and the moving of the University of Tasmania (in whole or in part) to the site. Any such development, if it occurs after the development of the NSLRS, will need to be cognizant of it.

13 The Hobart City Council overcame opposition to running heritage trams on the Hobart waterfront gaining planning prerequisites.

5 Cost Benefit Analysis

In this chapter, we provide an overview of the cost benefit analysis, incorporating a discussion of the methodology used, and our results.

5.1 Process of analysis

The basic inputs for the cost benefit analysis come from the demand analysis and subsequent calculation of consumer surplus in Chapter Two, and the cost analysis in Chapter Four. The change in the consumer surplus is the basis for the calculations of the societal benefits. To account for population growth, we grow the size of the change in consumer surplus by the weighted average of the growth of population predicted by Tasmanian Treasury (according to its most likely scenario). This implicitly assumes that the consumer surplus is the same on a person-to-person basis.

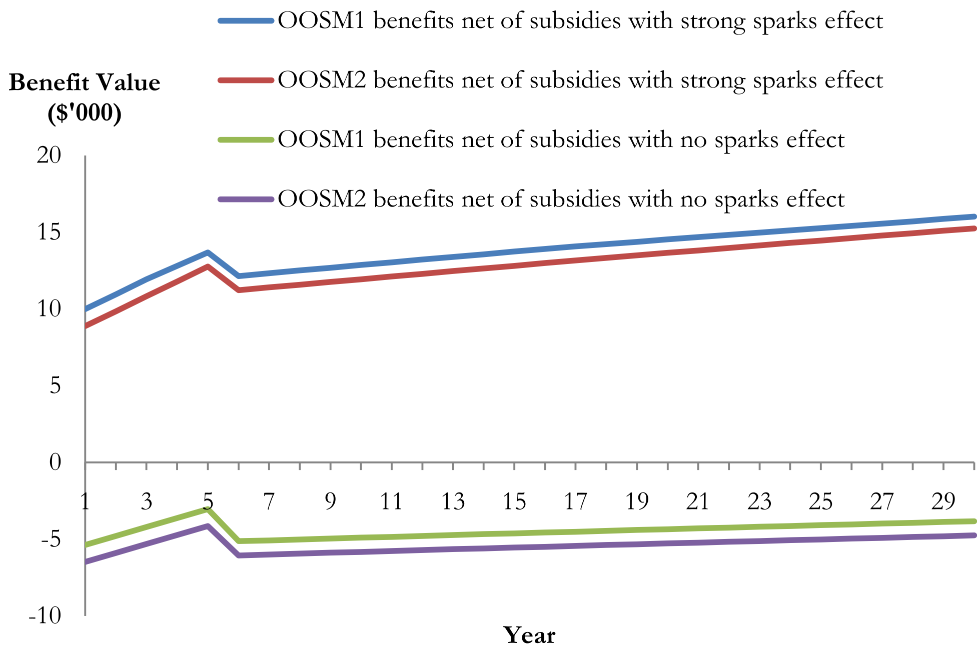
From the consumer surplus, we subtract the change in subsidy (increased by the excess burden of 20 percent, as discussed) required to operate the train system in addition to the bus system. The feeder bus system we use in Chapter Two has been designed (by DIER) to be cost neutral. That is, some buses competing with the rail are removed, and the costs associated with them allocated to providing better feeder-bus services for the train system. Thus, the change in subsidy is the net subsidy per annum associated with the introduction of the rail. This subsidy is calculated as being the number of rail patrons, multiplied by a fare of $2.68, minus the annual capital and operating costs shown in Chapter Four.[14] Many customers in Hobart receive concessional fares, and hence do not actually pay the current full adult fares of $2.50 or 3.70. However, the decision to provide a concession on the part of government is nothing to do with the operation of the NSLRS, but is rather a separate policy decision designed to improve travel opportunities for children, unemployed people and others the Tasmanian government has deemed worthy of receiving concessional fares.

The results of the analysis are shown in Figure 6. Note that in the no sparks effects case, the size of the required subsidies actually exceed the gain in consumer surplus, due to relatively low patronage. This means that the "benefits" of the NSLRS are negative.

---

14 We assume the railway will be subject to the same fares as the existing bus service. The fare reflects the fact that roughly half the patronage originates from beyond Glenorchy (where current metropolitan bus fares to Hobart are $3.70 not $2.50 and those to Glenorchy are $2.50), but 50 percent of patrons make use of Green Cards which provide a 20 percent discount. Unlike the concession payment, the Green Card is a public transport company decision aimed at increasing patronage.

Figure 6 **Benefits net of subsidy costs**



The timeframe of analysis is 30 years, so the net present value of both the costs and benefits is determined by applying discount rates of four, seven and ten percent to each stream of benefits and costs. The benefit cost ratio is then the net present value of the benefits divided by the net present value of the costs, and the net benefit is the former minus the latter.

5.2 Results

In this section, we provide the results of the analysis, undertaken for the likely maxima and minima of demand; the strong and no sparks effect cases.

Table 2 **Benefit cost analysis results**

	Strong Sparks Effect		No Sparks Effect	
	Benefit cost ratio	Net benefit ($ mil)	Benefit cost ratio	Net benefit ($ mil)
OOSM 1 (Diesel Vehicles)				
4 % disc rate	1.11	22.7	0.0	-268.8
7 % disc rate	1.10	14.5	0.0	-191.5
10 % disc rate	1.09	9.9	0.0	-144.2
OOSM 2 (Electric Vehicles)				
4 % disc rate	0.97	-7.3	0.0	-299.6
7 % disc rate	0.95	-7.4	0.0	-213.8
10 % disc rate	0.94	-6.9	0.0	-161.4

The results of the analysis point to some stark differences. If the sparks effect is as strong as suggested by the discussion in Chapter Two, then the NSLRS appears to be viable, providing it uses the least expensive option of diesel rolling stock. Bear in mind that this result does not include the cost to government of any concessions on fares, which would result in a benefit cost ratio of less than one.

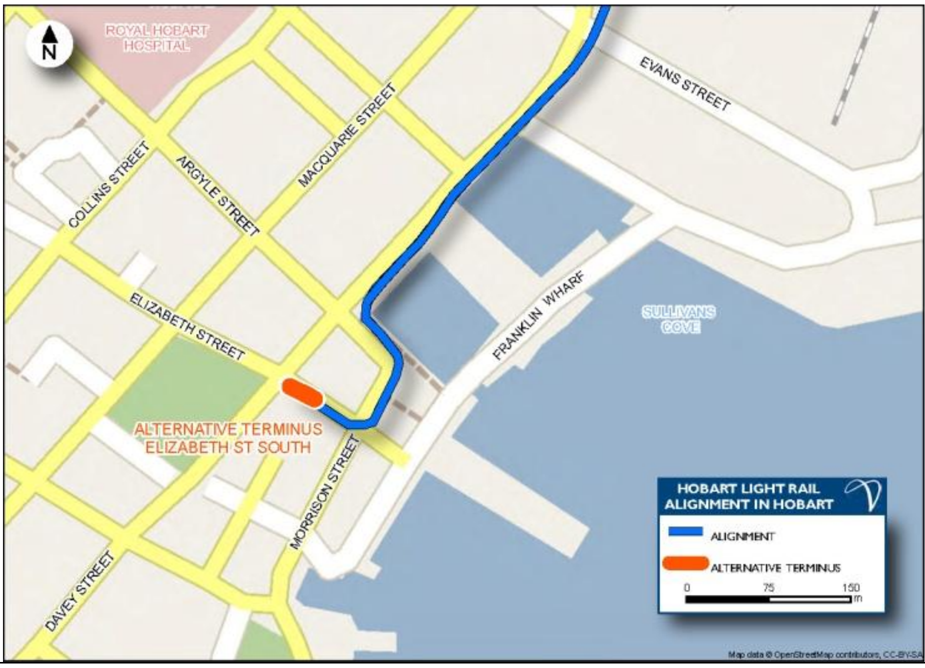
If the sparks effect does not exist, the project is clearly unviable. The basic problem is that the improvement in consumer surplus is so small that it is swamped by the cost of subsidies needed to cover the costs of the NSLRS, giving negative "benefits". This, in turn, arises because too few people obtain travel-time savings from switching to rail, and thus do not do so. The net result is that the no sparks effect case can only have a benefit-cost ratio of zero (the minimum) and incurs substantial net costs.

The basic question for policymakers is whether the sparks effect exists, and whether it is as strong as suggested in Chapter Two. It is feasible that a sparks effect may exist and be as strong as Newman (2011) reports for Perth. However, if this strong sparks effect does not eventuate, the NSLRS presents considerable risk of substantial losses.

Elizabeth St extension

The Stage Two Report examined a possible extension of the line from Mawson Place to Elizabeth Street, which would cost $2.5 million and provide a small time saving. We model this by including the cost as part of the asset base, and by increasing the consumer surplus by five percent, which is equivalent to making the NSLRS a couple of minutes faster than the other modes of transport. The map of this extension is shown in Figure 7, and the results in Table 3.

Figure 7 **Elizabeth St extension**



Source: Stage Two Report

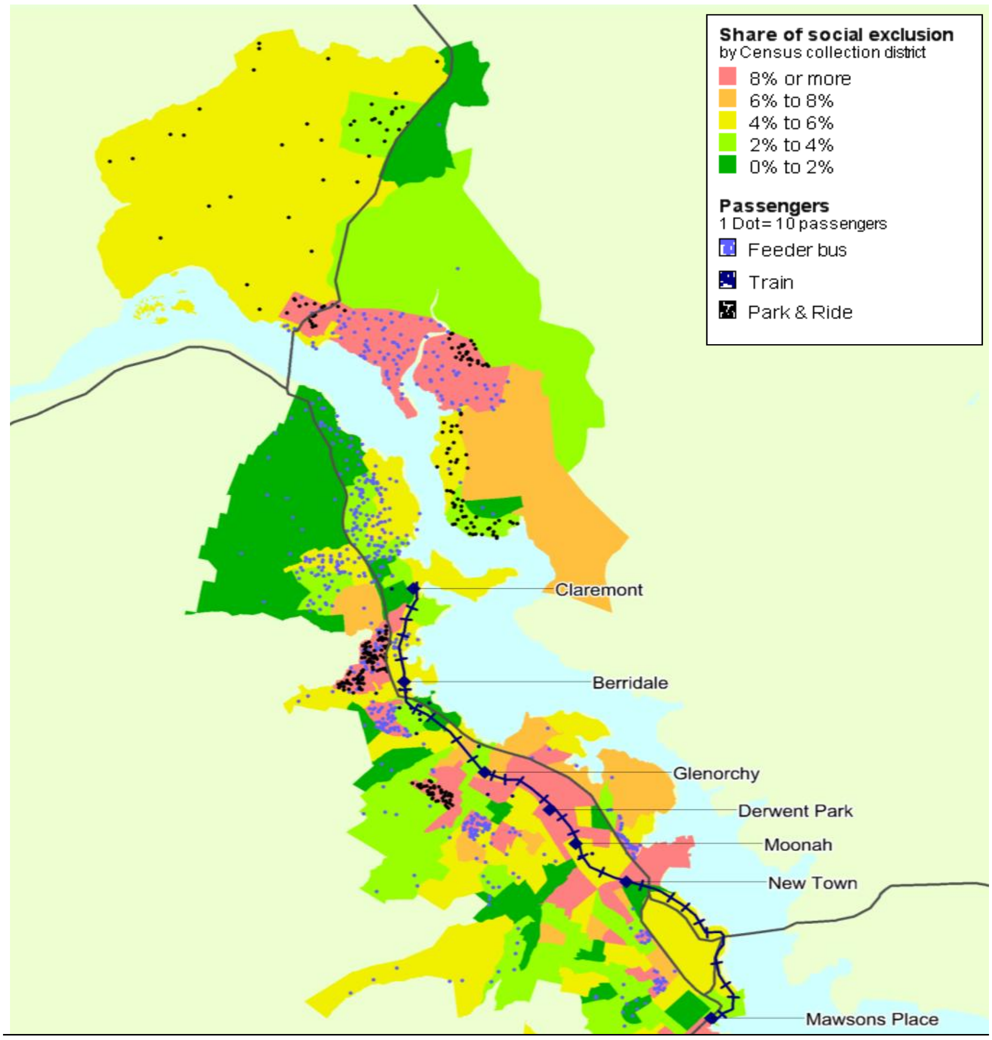
Table 3 **Elizabeth St extension results (strong sparks effect case)**

	Benefit Cost Ratio	Net Benefit ($ mil)
OOSM 1 (diesel vehicles)		
4% disc rate	1.13	$26.99
7% disc rate	1.12	$17.33
10% disc rate	1.11	$12.01
OOSM 2 (electric vehicles)		
4% disc rate	0.99	-$3.30
7% disc rate	0.97	-$4.75
10% disc rate	0.96	-$5.01

5.3 Distributional issues

An important component of a benefit cost analysis is who bears the costs and who enjoys the benefits. In this instance, the major costs associated with the NSLRS are in its construction, and these costs are distributed across the whole of Australia (in the event of funding by the Commonwealth Government). In order to understand who benefits, we examine the number of trips on the NSLRS by location and then cross reference to the socio-economic characteristics of each of those locations. The results are shown in Figure 8.

Figure 8 **Public transport use by collection district**



Note: The points within each collection district are randomly placed and do not represent actual places of residence.
Data Source: ACIL Tasman modelling

In the case where a strong sparks effect prevails, the service provided by the NSLRS has a positive distributional effect. Note, moreover, that the service is particularly effective in connecting Brighton and Bridgewater (via feeder bus services) to the rest of the city. Since both of these areas contain relatively large numbers of marginalised people, this is a positive distributional impact of the NSLRS.

6 Sensitivity Analysis

The purpose of a sensitivity analysis is to provide an understanding of how robust the findings are to changes in the assumptions which underpin the analysis. We have approached the sensitivity analysis by making use of a Monte Carlo framework, which allows us to develop a distribution around the benefit cost ratios based upon sampling from distributions around the most likely values of its key inputs. This is a much more robust approach than simply inputting a few different values for some of the major inputs.

In undertaking our sensitivity analysis, we are mindful of the Infrastructure Australia requirements to include:

- Capital costs
- Construction duration and therefore opening date
- Operating (including maintenance) costs
- Under and over estimation of the benefits (typically demand for the service)
- Changes in global oil prices
- Fluctuations in carbon prices; and
- Different population growth/decline scenarios and set out the value of each benefit for each forecast year.

We divide our approach into the benefits side, and the costs side, describing the process in each, and then presenting the results of our analysis.

Note that we only consider the strong sparks effect scenario in the formal sensitivity analysis below, because the negative "benefits" that prevail in the no sparks effect case render the BCR meaningless, and the highly negative net benefits mean that even large changes in assumptions make little difference to the overall conclusions. However, a rough idea of the robustness of the strong sparks effect and no sparks effect conclusions can be gained from the analysis shown in Table 4. Here, the patronage in the no sparks effect case (strong sparks effect case) is increased (decreased) in increments (decrements) of ten percentage points, and the consumer surplus is similarly changed to ascertain the effect this has on benefit cost ratios and net benefits.

Table 4 **Effects of increasing and decreasing patronage**

	Benefit cost ratios						Net benefits ($ mil)					
	OOSM1 (Diesel vehicles)			OOSM2 (Electric vehicles)			OOSM1 (Diesel vehicles)			OOSM2 (Electric vehicles)		
	4% Disc. Rate	7% Disc. Rate	10% Disc. rate	4% Disc. Rate	7% Disc. Rate	10% Disc. rate	4% Disc. Rate	7% Disc. Rate	10% Disc. rate	4% Disc. Rate	7% Disc. Rate	10% Disc. rate
Strong sparks case	1.110	1.099	1.091	0.967	0.953	0.941	$22.786	$14.487	$9.968	-$7.268	-$7.450	-$6.955
90% of strong sparks	0.882	0.872	0.864	0.751	0.737	0.727	-$24.462	-$18.855	-$14.957	-$55.219	-$41.225	-$32.175
80% of strong sparks	0.651	0.641	0.635	0.534	0.522	0.513	-$72.435	-$52.641	-$40.184	-$103.19	-$75.012	-$57.402
70% of strong sparks	0.419	0.411	0.405	0.317	0.307	0.299	-$120.41	-$86.428	-$65.411	-$151.16	-$108.80	-$82.629
170% of no sparks	0.144	0.128	0.113	0.052	0.035	0.019	-$162.53	-$117.09	-$89.117	-$193.29	-$139.46	-$106.33
160% of no sparks	0.065	0.050	0.036	0.000	0.000	0.000	-$177.56	-$127.58	-$96.883	-$208.31	-$149.95	-$114.10
150% of no sparks	0.000	0.000	0.000	0.000	0.000	0.000	-$192.58	-$138.07	-$104.65	-$223.34	-$160.44	-$121.87
140% of no sparks	0.000	0.000	0.000	0.000	0.000	0.000	-$207.61	-$148.57	-$112.41	-$238.36	-$170.94	-$129.63
130% of no sparks	0.000	0.000	0.000	0.000	0.000	0.000	-$222.63	-$159.06	-$120.18	-$253.39	-$181.43	-$137.40
120% of no sparks	0.000	0.000	0.000	0.000	0.000	0.000	-$237.66	-$169.55	-$127.95	-$268.41	-$191.92	-$145.16
110% of no sparks	0.000	0.000	0.000	0.000	0.000	0.000	-$252.68	-$180.05	-$135.71	-$283.44	-$202.42	-$152.93
No sparks case	0.000	0.000	0.000	0.000	0.000	0.000	-$267.71	-$190.54	-$143.48	-$298.46	-$212.91	-$160.69

The conclusions from Table 4 are clear; small changes in the parameters of the strong sparks effect case have quite substantial effects on the benefit cost ratios and net benefits, whereas even very large changes in the no sparks effect case have a limited effect on the conclusions as to the viability of the NSLRS under this scenario.

We now turn to the formal sensitivity analysis.

6.1 Benefits

For benefits, the demand model contains variation in travel speeds, fuel prices and ticket prices. The model produces a large number of "least cost options" from which we draw the demand curves. However, the demand curve are lines of best fit derived via regression analysis, which means that we can utilise the regression error terms in sensitivity analysis. In so doing, we cover the fourth, fifth and sixth of the dot points associated with Infrastructure Australia's requirements above.

We do not cover different population forecasts in our model. This is because the structure of the model is based around estimating the consumer surplus each year for a given population. Thus, in order to incorporate uncertainty around population forecasts, we instead do our sampling of costs and benefits three times; once for each of the Tasmanian Treasury population growth scenarios; most likely, low growth and high growth. The number of trips per person, and the distribution of people in each area of Hobart remain the same, but the overall number of people varies according to the growth scenario chosen.

6.2 Costs

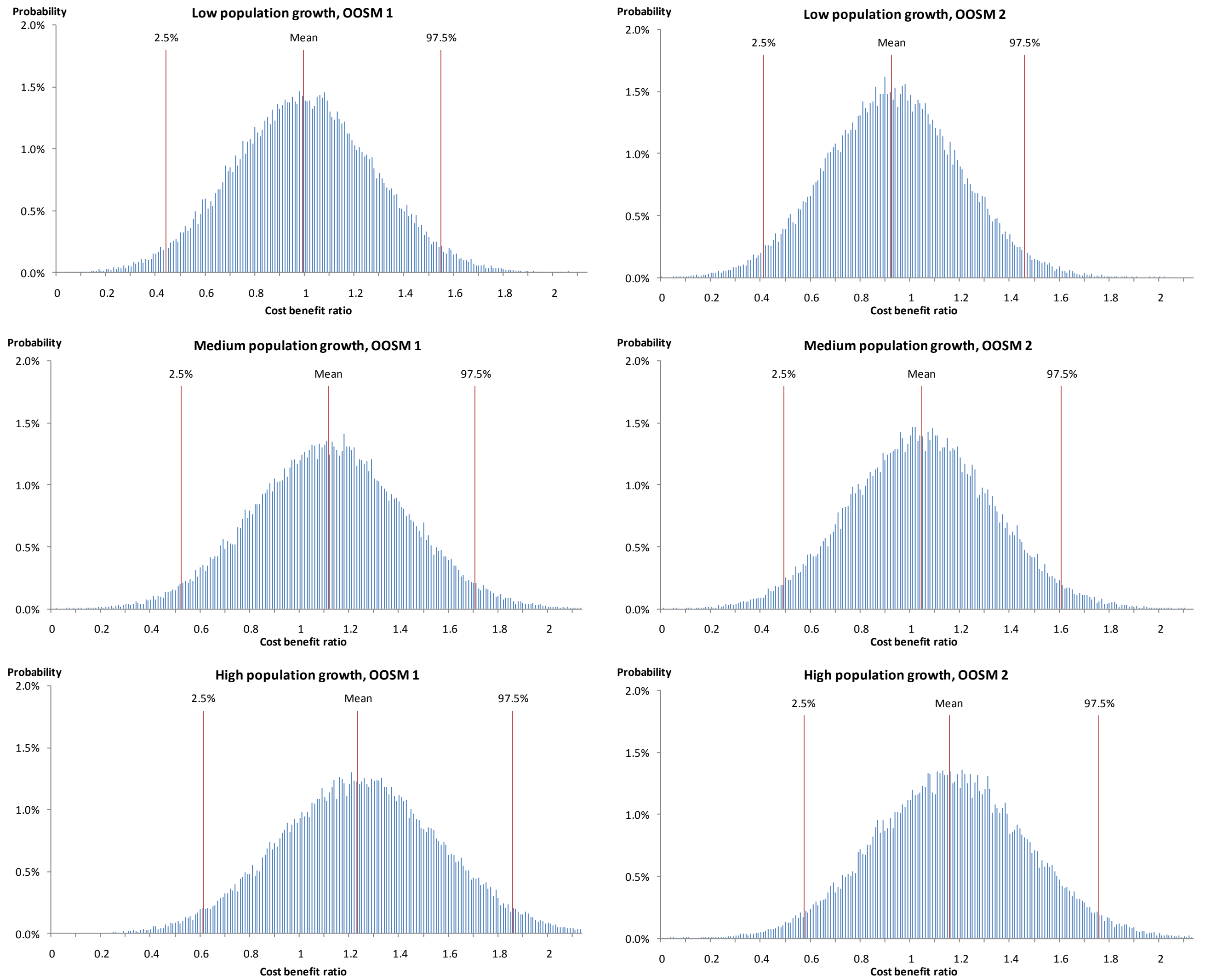
In the Stage Two report, Hyder present point estimates for costs, but they also undertake a "risk analysis" which shows the distribution of potential costs around the most likely scenario of their point estimates. We make use of this distribution to conduct the sensitivity analysis in costs. The risks that drive the risk distribution cover the first two dot points from Infrastructure Australia above. They do not explicitly cover operating costs. However, operating costs are between five and ten percent of total costs, and would thus not make a substantial difference to the cost distribution in the Stage Two Report.

6.3 Sensitivity analysis results

Our sensitivity analysis is formed by taking a random draw from each mode's consumer surplus distribution and a random draw from the cost distribution, and then forming an estimate of the relevant net benefit and benefit cost ratio. In order to form a benefit (ratio) distribution, this process is repeated 50,000 times for both cost scenarios, OOSM 1 (diesel vehicles) and OOSM 2 (electric vehicles).

As noted above, since variation in population does not enter the basic model, we have instead opted to repeat the process of benefit and cost sampling three times, to reflect the different Tasmanian Treasury forecasts. With each sampling run incorporating 50,000 samples drawn to build a distribution, this means we sample a total of 150,000 times for each cost scenario. The results of this approach are shown in Figure 9 below, with the 95 percent confidence intervals shown in the distribution.

Figure 9 **Cost benefit ratio distribution**



All six histograms follow a normal distribution. The different population scenarios do not affect the shape of the distribution but move it sideways. Consequently, the low population is associated with an expected cost-benefit ratio is marginally below one for both cost scenarios.

7 Conclusions

This report provides an overview of the third stage of the project, which incorporates a detailed demand analysis, and ascertains the net benefits of the proposed railway, taking into consideration the costs of the optimal operating service models (OOSMs) derived in Stage Two.

The analysis is grounded in notions of consumer surplus. We develop demand curves for all modes of transport before and after the introduction of the NSLRS using a spatial model of total resource cost minimisation on the part of consumers. Variance in the inputs gives rise to large numbers of price-quantity points for each mode and regression analysis is used to fit a demand curve to these points. We include in our resource costs of travel the cash costs, time costs and various externalities, thus internalising these costs into the consumer decision. We calculate the consumer surplus associated with each demand curve, and then compare the overall consumer surplus situation prior to and after the introduction of the NSLRS. The difference is the benefit of the system in each scenario examined, which is then compared (after subtracting any required subsidies) with the costs of developing the NSLRS.

The model is based upon a notion of cost minimisation, but railways can generate patronage above and beyond that which a model of their cost to users would predict, because of the relative attractiveness of railways for users compared to other public transport modes. One key example is Perth, where the replacement of a bus route (including some of which used dedicated lanes) with a train down the centre of the Kwinana Freeway resulted in patronage on the route more than tripling (Newman, 2011). We want to be able to account for this sparks effect, and we thus calibrate the model to produce a modal share for rail which matches this very strong sparks effect in Perth.

However, we also recognise that, since there is limited understanding of what drives the sparks effect (or at least, a sparks effect this large), it is difficult to ensure that it occurs in Hobart. We thus examine a version of the model where the effects of this strong sparks effect have been removed. Further, we also examine smaller potential sparks effects to ascertain how they affect the viability of the NSLRS.

The difference between the strong sparks effect and no sparks effect cases is stark; the consumer surplus in the latter case is only roughly a fifth of that prevailing in the former case, and is insufficient to overcome the total subsidy cost required to operate the NSLRS. The result is a negative stream of benefits. In benefit cost terms, this means that, while a strong sparks effect can generate a benefit cost ratio that just exceeds one, the lack of a sparks effect generates a cost benefit ratio of zero, and very large social costs.

Moreover, when we examine smaller sparks effects by increasing demand (and consumer surplus) from the no sparks effect base, and decreasing them from the strong sparks effects maximum, we find an asymmetry. The benefit cost ratio in the strong sparks effect case diminishes sharply with even small reductions in patronage, whilst we require an increase in patronage of sixty percent above the no sparks effect case level to achieve benefit cost ratios greater than zero.

The authors are agnostic about the existence or otherwise of a sparks effect associated with the NSLRS (and consider that there is insufficient objective evidence to predict its likely size). We note that empirical cases exist where the replacement of a bus route with a rail route have resulted in large increases in patronage, but note also that clear reasons as to why this might occur (absent of the train being faster than the bus) have not been forthcoming, or seem relatively small compared to the size of the effect.

For this reason, we do not make predictions about the likely size of any sparks effect. Rather, we suggest that a benefit cost ratio slightly in excess of one requires a strong sparks effect (roughly equal to that cited by Newman, 2011, for Perth), but that smaller sparks effects will produce much less favourable results. Overall, our conclusion is that positive social benefits for the NSLRS are a feasible outcome, but the project is one which carries very high risks.

Bibliography

Australian Bureau of Statisitics, 2011, *Average Weekly Earning, Australia, ABS* Cat. 6302.0.

Australian Bureau of Statistics, 2002, *Survey of Motor Vehicle Use,* ABS Cat. 9208.0.

Australian Bureau of Statistics, 2006, *Census.*

Australian Institue of Petroleum. (n.d.). *National Metropolitan Reatail Unleaded Petrol Prices*, available from www.aip.com.au/pricing/retail/monthly/index.htm

Australian Transport Council, 2006, *National Guidelines for Transport System Management in Australia,* available from www.atcouncil.gov.au/documents/

Bureau of Infrastructure, Transport & Regional Economics (BITRE), 2009, *Australian Transport Statistics Yearbook,* available from www.btre.gov.au/info.aspx?ResourceId=710&NodeId=50.

Bureau of Infrastructure, Transport & Regional Economics (BITRE), 2007, *Estimating Urban Traffic and Congestion Cost Trends for Australian Cities*, BITRE Working Paper 71, available from www.btre.gov.au/info.aspx?NodeId=23&ResourceId=249.

Bureau of Infrastructure, Transport & Regional Economics. (BITRE), 2009, *Cost of Road Crashes Australia,* available from www.btre.gov.au/info.aspx?NodeId=26&ResourceId=47.

Department of Economic Development (DED), 2008, *Industrial Land Demand Tasmania – Short to medium term overview*, Departmental Report April, 2008.

Department of Infrastructure, Energy and Resources (DIER), 2010, *Greater Hobart Household Travel Survey,* available from www.transport.tas.gov.au/miscellaneous/greater_hobart_household_travel_survey.

Department of Infrastructure, Energy and Resources (DIER), 2010, *Tasmanian Urban Passenger Transport Framework*, available from www.dier.tas.gov.au/passenger_transport/passengertransportframework.

Department of Infrastructure, Energy and Resources (DIER), 2011, *Congestion in Greater Hobart*, mimeo.

Department of Infrastructure, Energy and Resources, (DIER), 2009, *Review of Passenger Travel Demand Measures Greater Hobart*, available from www.dier.tas.gov.au/passenger_transport/hobart_passenger_transport_case_study

Department of Prime Minister and Cabinet, Social Inclusion Unit, 2008, *Social Inclusion: Origins, Concepts and Key Themes,* available from www.socialinclusion.gov.au/Resources/Pages/Resources.aspx.

Glenorchy City Council, 2006, *Main Road Corridor Master Plan.* December 2006.

Hobart City Council (HCC), 2009, *Sustainable Transport Strategy 2009 – 2014*.

Hurni, A, 2006, *Transport and Social Disadvantage in Western Sydney*. Western Sydney Community Forum, available from www.wscf.org.au/publications/.

KPMG, 2010, *CGE Analysis of the Current Australian Tax System*, Consultancy Report for the Australian Department of Treasury

Lucas, K, Grosvenor, T & Simpson, R, 2001, *Transport, the Environment and Social Exclusion*. Report produced for the Joseph Rowntree Foundation, available from www.sortclearinghouse.info/research/316/.

Myriad Consultancy, 2010, *Park and Ride Commuter Transport,* Consultancy report for DIER, Sept 2010.

Newman, P, 2007, *Planning for Transit Oriented Development in Australian Cities*. BEDP Environment Design Guide, DES 15, November 2007.

Newman, P, 2011, *Getting on Board the Hobart and Northern Suburbs Railway: Creating a Sustainable and Prosperous City,* presentation to the Northern Suburbs Rail Action Group, Hobart, April 7th 2011.

Parry, IW, & Small, KA, 2009, "Should Urban Transit Subsidies Be Reduced?", *American Economic Review* , 99(3), 700-24.

Planning Institute of Australia Tasmania Division (PIA), 2008, *The Hobart Western Shore Public Transport Corridor*. Infrastructure Australia Submission. October, 2008.

SEU. (2003) *Making the Connections: Transport and Social Exclusion*. London: Social Exclusion Unit, Office of the Deputy Prime Minister, United Kingdom, available from www.sortclearinghouse.info/research/245/.

Southern Tasmanian Councils Authority (STCA), 2010, *Regional Land use Strategy – Background Report No. 8*: *The regional transport system*. September, 2010.

Southern Tasmanian Councils Authority (STCA), 2011, *Regional Land use Strategy – Background Report No. 12*: Industrial Activity. March, 2011.

Stanley, J., Hensher, D. A., Stenley, J., Currie, G., Greene, W. H., & Vella-Brodrick, D. (2010). *Social Exclusion and the Value of Moblity*, ITLS Working Paper 10-14, available from sydney.edu.au/business/itls/research/publications/working_papers/2010

Transportation Research Board (TRB), 2004, *Transit-Oriented Development in the United States: Experiences, Challenges, and Prospects.* Transit Cooperative Research Program Report 102. January, 2004

Varian, HR, 2006, "Revealed Preference", in Szenberg, M, Ramrattan, L & Gottesman, AA (eds), *Samuelsonian Economics and the 21st Century*, New York: Oxford University Press, 99-115

Winston, C & Maheshri, V, 2007, "On the Social Desirability of Urban Rail Transit Systems", *Journal of Urban Economics,* 62, 362-82.

A Details on Demand Model

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.

A.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 train 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.
- The costs of social exclusion.[15]

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.

For some consumers who are deemed socially excluded (see discussion below), a countervailing benefit associated with the alleviation of social exclusion through better (public) transport options is included.

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

15 We have not included the costs of road maintenance, as advice from DIER engineers is that the marginal effect of cars on roads designed for trucks is close to zero.

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 A1.

Table A1 **Variables of the cost functions**

Description	Variable name	Affected mode
Distance to work car	*DC*	Car
Distance to work bus	*DB*	Bus
Distance to work train	*DT*	Train
Distance to closest train station feeder	*DF*	Feeder (train)
Distance to closest P&R	*DPR*	P&R (train)
Distance to closest bus stop	*WD_B*	Bus
Distance to closest train station	*WD_T*	Train
Distance to closest feeder stop	*WD_F*	Feeder (train)
Distance non-directed trip	*DL*	All
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 train	*TS*	Train (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
Inner distance	*ID*	Car and Bus
Parking cost	*PC*	Car
Pollution cost	*EPC*	Car
Road crash cost	*ERC*	Car

The cost functions (*C*) by mode and journey type are:

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

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

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

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

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

$$C_{non-directed}(Car) = \left[DL * FC * FP + \frac{DL}{CSo} * VTT + EPC * DL + ERC * DL\right] / DL$$

$$C_{non-directed}(Bus) = \left[TP + \frac{WD_B}{WS} * VTT + WT * VTT + \frac{DL-WD_B}{BSo} * VTT\right] /DL$$

$$C_{non-directed}(Train) = \left[TP + \frac{WD_T}{WS} * VTT + WT * VTT + \frac{DL-WD_T}{TS} * VTT\right] /DL$$

$$C_{directed}(Feeder) = \left[TP + \frac{WD_F}{WS} * VTT + WT * VTT + \frac{DF}{BSo} * VTT + \frac{DL-WD_F-DF}{TS} * VTT\right] / DL$$

$$C_{non-directed}(P\&R) = \left[TP + \frac{DPR}{BSo} * VTT + WT * VTT + \frac{DL-DPR}{TS} * VTT\right] /DL$$

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 204 Census collection districts throughout Northern suburbs of Hobart (see Figure 2 in Chapter Two) to obtain representative consumers. The basic assumption is that each representative consumer lives at the centre of each collection district and travels, in the case of the directed travel, in a straight line from this point to the centre of Hobart or Glenorchy.[16] We delineate between employed people, students and the unemployed in each collection district, and consider income levels in the context of examining the impact transport has on overcoming social exclusion.

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 point just north of Glenorchy (DIER, 2011), and we allow all speeds (except those of the NSLRS) to vary in the creation of demand functions. Fuel prices (which we also allow to vary) are from the Australian Institute of Petroleum and data on pollution costs come from the Australian Transport Council (2006) while those on road crashes come from BITRE (2009). These are the latest figures available in each case. Other parameter information is provided below.

16 We recognise that neither the NSLRS nor the roads carrying buses and cars travel in straight lines. However, the complexity of routes for buses and cars makes it very difficult to derive an "as travelled" distance. Moreover, random checks on locations in the model indicate that the error is roughly the same for road and for rail, meaning relative differences between the various modes of travel are largely unaffected.

Waiting time

A detailed analysis of average waiting time was conducted by Parry & Small (2009). They find that for frequencies (*H*) of 15 minutes or less, passengers arrive randomly. For larger headways travellers tend to plan their trip. These results lead to the following waiting time functions:

$$WT = \begin{cases} [H/2\,]/60 & for\ H \leq 15 \\ [6 + 0.2 * H/2]/60 & for\ H > 15 \end{cases}$$

Average fuel consumption

In 2002 the Australian Bureau of Statistics (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 25 per cent mark-up to account for stop-and-go driving when roads are congested.

Ticket price

The value of the ticket price ($1.50) is taken from the Stage One Report. It includes concessions, which is why it is lower than the current bus ticket prices of $2.50 and $3.70. In effect, it is the average out-of-pocket cost of a ticket to consumers. We use this figure because it is the out-of-pocket price which drives consumer choice.

Value of travel time

The cost of travel time is generally valued as a fraction of the average gross hourly wage. According to the ABS (2011) the average gross hourly wage in Tasmania is about $28. We assumed a travelling time discount factor for Australia of 60 per cent, which is half way between the average net to gross income ratio (70 per cent) and similar discount factors estimated in the USA by Parry and Small (2009) of 50 per cent.

Parking cost

We assume the average expected parking cost in Hobart to be $3 per day. The early bird rate in the centre is $10 per day, but only around a third of people working in Hobart actually pay for parking (Myriad Consultancy, 2010). Moreover, we work on the basis of representative consumers, and a car often carries more than one person to work.

A.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 collection district and a given place of work or education, whilst undirected travel is travel from a given Census collection district on a trip of uniform length, but no particular direction. 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 collection district 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 either the centre of Hobart (70 percent) or the centre of Glenorchy (30 percent), based upon Census data on the numbers of people employed in these two 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 NSLRS, 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 NSLRS 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. We assume schools are located in Hobart, rather than along the line, which has the effect of increasing the length of a train ride, but not the number of rides. As with workers above, the effects are small.[17]

Non-directed travel specific assumptions

Non-directed trips include trips for leisure, trips to visit tourist attractions and special events, trips for shopping and other similar trips without an easily definable destination. Since the range of possible destinations is so large, rather than trying to assign particular destinations for these kinds of trips (such as MONA or the shopping centre at Glenorchy) we assume that each representative consumer makes undirected trips of uniform length until the marginal utility from doing so is exceeded by the cost of the final trip. The uniform length of these trips is 11 km, which is the average for "leisure" trips in the Greater Hobart Travel Survey (DIER, 2010).

The major difficulty in our approach is that measuring utility between people is widely considered to be impossible. We therefore make use of the cost functions, the Greater Hobart Travel Survey and the theory of revealed preference (see, for example, Varian, 2006).

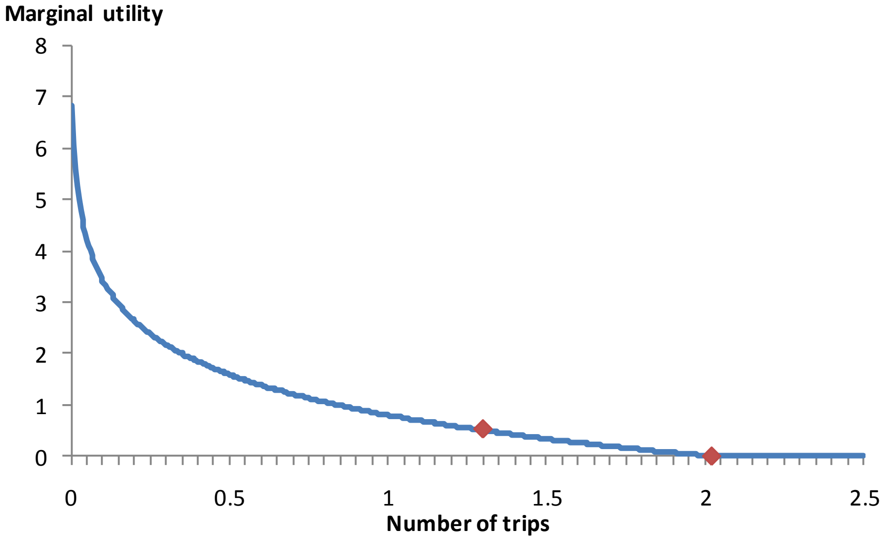
The survey reports that each person undertakes an average of 2.7 trips on a weekday and 4.4 trips on weekends. Assuming that 2 of the weekday trips are directed (e.g. to work), each individual makes about 1.28 non-directed trips per day. From the cost model, we know that a car trip (the dominant mode) costs $0.52 per kilometre, so if each person travels until marginal cost equals marginal revenue, the marginal utility of the last trip made by the marginal consumer should be $0.52.

Another finding from the survey is the standard deviation from the average number of trips which amounts to 0.36 (DIER, unpublished data from DIER 2010). Assuming normal distribution, this means that 95 per cent of the travellers undertake less than 2.02 non-directed trips per day. Therefore we set the marginal utility of every trip additional to 2.02 to zero.

This provides us with two data points upon which to fit a curve. Economic theory generally assumes utility functions are curved, so we make use of a logarithmic function; implicitly assuming that marginal utility decreases at a fixed rate. The resulting marginal utility function is shown in Figure A1.

[17] Those over 20 are likely to be university students who would, in many cases, use buses from Mawson Place to the University of Tasmania. In the model, only their trip to Hobart is included.

Figure A1 **Marginal utility of non-directed trips**



Source: ACIL Tasman modelling based on the Greater Hobart Household Travel survey *(Department of Infrastructure, Energy and Resources, 2010)*

We make use of this utility function by allowing every consumer to keep making leisure trips until the cost of the last trip she makes exceeds the relevant point on the curve in Figure A1 above.

Social inclusion and exclusion

One important aspect of non-directed trips is social inclusion and exclusion. Social inclusion is a term that refers to whether a person has the resources, opportunity and capability to learn, work, engage (connect with people, use local services and participate in local, cultural, civic and recreational activities), and have a voice; influence decisions that affect them (Department of Prime Minister and Cabinet, Social Inclusion Unit, 2008). Social exclusion occurs when constraints prevent adequate participation in these activities.

For socially excluded people, the ability to access transport is crucially important as it provides them with an opportunity to engage with the wider community. One study of the value of transport to the socially excluded (Currie et al, 2010) suggests that it can be as high as $19.30 per trip, and that it declines with income.

The Census data do not allow us to delineate socially excluded people exactly as defined above (Currie, et al, 2010 made use of survey to do so), so we instead take as socially excluded all those in each collection district who are unemployed and earn less than $250 per week. For these people, we subtract from their (public) transport costs a social exclusion amelioration benefit derived from Currie, et al (2010, p13). We then take a weighted average of this cost, and the cost of travel for the non-excluded representative consumer in that collection district, and use this as the cost of (public transport) travel for that particular collection district. The net result is that there are more non-directed trips because of the presence of socially excluded people in an area, and that the number increases as the number of socially excluded people increases. As the public transport system improves (such as with the introduction of the NSLRS) and becomes more popular with people in general, its utility to the socially excluded increases still further because of the adjustment process outlined above.

A.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 A2.

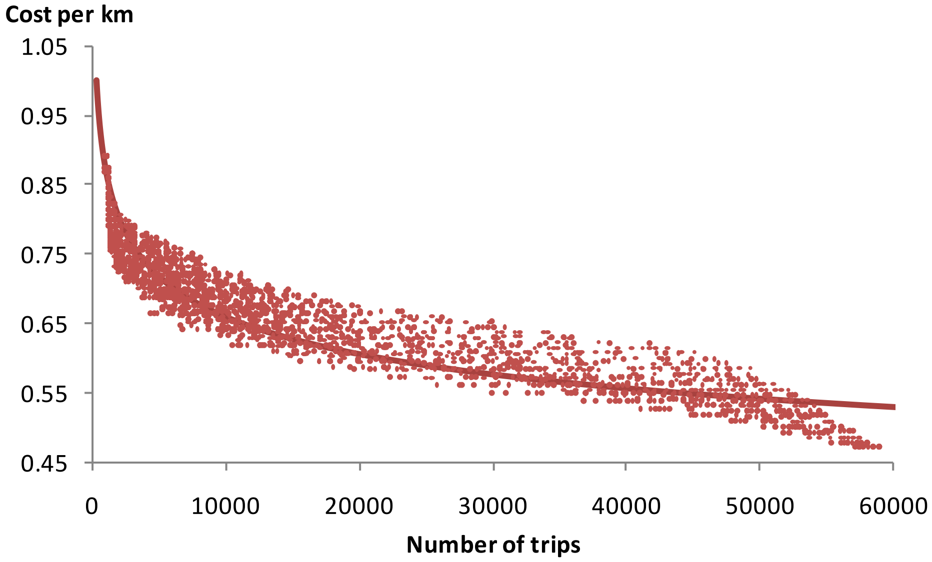
Table A2 **Parameters and their variation in the model**

Variable	Min	Max	Increment
Average speed car outer (km/h)	53.0	57.0	2.0
Average speed car inner (km/h)	36.0	40.0	2.0
Average speed bus (km/h)	43.0	70.0	2.0
Average speed bus inner (km/h)	30.0	60.0	2.0
Fuel price ($)	1.2	2.0	0.1
Ticket price ($)	0.1	3.0	0.1

Source: ACIL Tasman modelling

The process by which the demand curves are derived is as follows. For each collection district, 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 cost per unit of distance travelled for the whole range of minimal cost choices for all possible permutations of the parameter ranges shown in Table A2 (roughly 500,000 for each of the five types of trip and for directed and non-directed trips). An example of such a scatter plot is shown in Figure A2, with the relevant demand curve fitted to it.

Figure A2 **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 logarithmic functional form, because this provides constant elasticity of substitution along the demand curve (which is a useful economic property) and because it provides a good fit. The variation, or "errors" from the regression are used in the sensitivity analysis in Chapter Six.

The consumer surplus is the area under each demand curve at the prevailing price. We approximate consumer surplus as the sum of rectangles made up by trip increments and the cost associated with each increment up to the expected number of trips.[18] From the result we subtract 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 NSLRS cases minus the sum of the pre NSLRS cases. Note that we examine two post NSLRS cases; immediately following its introduction, and five years after it has been introduced, when Hobart has "reacted" by creating four TODs.

A.4 Checking the results

In order to assess the validity of the model predictions, we compare its outcomes with actual data; the Greater Hobart Travel Survey (DIER, 2010) for

[18] That is, a series of rectangles under the demand curve. This is a common way of approximating the integral (and indeed, how it was discovered) and is used because MS Excel does not calculate integrals.

the pre NSLRS case, and data on public transport use in cities around Australia from the ABS for post NSLRS cases. Since we compare the pre NSLRS case with the Greater Hobart Travel Survey, we calibrate model inputs to the time period of this survey. This affects, in particular, the fuel price, which was lower than it is in Hobart at present when the survey was undertaken. The relevant assumptions are shown in Table A3.

Table A3 **Parameter values used in model validation**

Description	Value	Unit	Source
Average speed car outer sector	55.00	km/h	Congestion in Greater Hobart (Department of Infrastructure, Energy and Resources, 2011)
Average speed car inner sector	38.00	km/h	Congestion in Greater Hobart (Department of Infrastructure, Energy and Resources, 2011)
Average speed bus outer sector	45.00	km/h	Department of Infrastructure, Energy and Resources, unpublished data (2011)
Average sped bus inner sector	32.00	km/h	Department of Infrastructure, Energy and Resources, unpublished data (2011)
Average speed walking	5.00	km/h	
Fuel price	1.20	$/l	Retail fuel prices September 2010 (Australian Institue of Petroleum)
Average fuel consumption	0.09	l/km	See Section A.1
Ticket price	1.50	$	See Section A.1
Value of travel time	16.80	$/h	See Section A.1
Inner distance	7.00	km	Congestion in Greater Hobart (Department of Infrastructure, Energy and Resources, 2011)
Parking cost	3.00	$/day	See Section A.1
Pollution cost	0.05	$/km	National Guidelines for Transport System Management in Australia (Australian Transport Council, 2006)
Road crash cost	0.08	$/km	Cost of road crashes Australia (Bureau of Infrastructure, Transport and Regional Economics, 2009)
Maximum capacity P&R	1,000		

For the post NSLRS cases, we make use of the same base data above, but add the NSLRS. We use the data above to make one model prediction on modal choice per collection district, and the modal shares are region-wide averages. This is in contrast to the formation of the demand curves, which make many predictions per collection district (and use a much wider variety of information than in Table A3 above) and derive demand curves by fitting a curve to the resultant scatter plots via regression analysis.

Pre-NSLRS

For the pre-NSLRS situation, the model predicts that 8.4 per cent of the sampled population choose the bus for directed transport and 6.3 percent for non-directed transport.

The Greater Hobart Travel Survey (DIER, 2010) reports that the bus share of education related trips is 9.5 per cent and that of trips to work is 4.6 per cent. However, this includes walking trips, which we exclude from our model. When these are excluded, the relevant figures are 13.2 and 5.7 percent respectively. Using shares of the population in each collection district who are employed and students, the (weighted) average of these two figures is roughly seven percent; midway between the model predictions.

Post NSLRS

For the post NSLRS case, we have two scenarios; the first five years as the city "reacts" by changing urban density and developing TODs, and the years after this when TODs are assumed to be in place. Table A4 shows the modal shares in each of these two scenarios.

Table A4 **Modal shares post NSLRS**

	Pre-TOD		Post TOD	
	Directed	Non-directed	Directed	Non-directed
Train	12.4%	6.6%	12.9%	9.7%
Access by foot	*0.4%*	*0.0%*	*0.9%*	*3.6%*
Access by bus	*9.9%*	*3.1%*	*10.0%*	*2.9%*
Access by car	*2.1%*	*3.5%*	*2.1%*	*3.2%*
Bus	6.2%	4.0%	6.1%	3.8%
Car	81.4%	89.4%	81.0%	86.6%

Data source: ACIL Tasman modelling

The large share of train access via feeder bus is partly a result of the model structure. We use the Census collection district centroid as proxy for the place of residence of each of its residents. Since there are far more bus stops than train stations, the likelihood of a bus stop being closer to a person's home than a train station is overstated in the model. As modelling each house individually would dramatically increase complexity and data at a household level is not available, we accept this shortcoming. According to research undertaken by DIER about 1,300 households whose residents will most likely catch the train live in walking distance (i.e. 800m or closer). In this case the share of persons walking to the train would increase to 24 per cent and that of persons catching a feeder bus decrease to 59 per cent. For the calculation of the consumer surplus we used these adjusted values.

To ascertain whether the modal shares the model predicts after the NSLRS has been developed are realistic, we compare them to public transport shares in other Australian cities. The relevant data are shown in Table A5.

Table A5 **Public transport shares of journey to work trips**

	Sydney	Melbourne	Brisbane	Adelaide	Perth
Single method using public transport	15.65%	9.68%	10.49%	8.14%	7.12%
Two method with bus or train as lead	2.31%	1.61%	0.66%	0.50%	1.16%
Three methods with bus or train as lead	0.55%	0.71%	0.30%	0.17%	0.38%
Total public transport share	18.50%	12.00%	11.44%	8.82%	8.67%

Data source: ABS Census (2006)

The comparison suggests that the Northern Suburbs of Hobart is likely to have public transport shares which reflect those of Melbourne and Brisbane, and are slightly less than those in Sydney. This appears high, but it should be considered that much of the population in the study live in relatively dense (by Hobart standards) areas, relatively close to the inner city. It is thus not particularly surprising that modal shares could be high, particularly if the public transport system becomes much more efficient and well-patronised.