HOBART LIGHT RAIL BUSINESS CASE

Optimal Operating Service Models

Hyder Consulting Pty Ltd
ABN 76 104 485 289
Level 16, 31 Queen Street
Melbourne VIC 3000
Australia
Tel: +61 3 8623 4000
Fax: +61 3 8623 4111
www.hyderconsulting.com

Department of Infrastructure, Energy and Resources

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Authors	Jim Forbes, George Vanek, Krste Taseski, Sally de Little
Checker	Dragan Stamatov
Approver	Steve Boshier

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EXECUTIVE SUMMARY

Hyder Consulting Pty Limited (Hyder) forms part of the team for delivery of the Light Rail Business Case for Hobart on behalf of the Department of Infrastructure, Energy and Resources (DIER). The Light Rail Business Case considers the options available for introduction of a light rail system within Hobart and delivers a cost benefit analysis based on the forecast passenger demand of the proposed system. The agreed corridor study area is between Claremont and Hobart.

As part of Hyder's project delivery, Optimal Operating Services Models (OOSMs) for introduction of a light rail system in Hobart have been developed. As part of the OOSM development process various elements have been considered resulting in two optimal options being developed. The elements considered included:

- corridor alignment
- existing track condition and configuration
- rolling stock options and use of electrification
- signalling options
- maintenance and stabling facilities

During the course of the study Hyder met with DIER representatives and various stakeholders including TasRail, Hobart Northern Suburbs Action Rail Group and Future Transport Tasmania.

A site inspection was undertaken to visually assess the existing rail corridor and the condition of the existing track. The site visit also considered options for terminus points at Hobart and Claremont, space availability for passenger stops, two track options and suitable locations for passing loops.

The existing track is used for freight services with a maximum speed limit of 45kph. Hyder understands that the line was opened on 01 November 1876. The line was duplicated between 1911 and 1936. The existing track configuration is a single line which is the more recently constructed track, and a cycle path which replaced the original single track.

The overall assessment of the existing line including a review of the existing documentation regarding track condition concludes that the track in its current condition and with the current speed limit is not adequate to use for passenger rail services. Therefore it is recommended that a certain level of track upgrade would be required in order to safely introduce passenger rail services. The level of upgrade required is directly commensurate with the modelled speed limits for the track to achieve the desired levels of service.

A number of parameters were used as terms of reference for this study. These included:

- use of narrow gauge was to be maintained
- 7 stops were identified
- use of boom gates at level crossings
- OOSMs should achieve a minimum 15 minute interval of service

Further details on the parameters are provided in Section 2.

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

In developing the options, rail modelling was used to establish a potential timetable to achieve 15 minute interval rail services based on speed limit scenarios. The rail modelling also assisted in determining the infrastructure requirements such as passing loops and rolling stock units.

Optimal Operating Service Models

Following analysis of the options considered for introduction of the light rail system, and based on the assumptions listed above, the report recommends two OOSM options.

OOSM 01

The first preferred operating model recommends

- Use of diesel powered units as operational rolling stock

All other elements are common with OOSM 02 and are described below.

OOSM 02

The second preferred operating model recommends

- Provision of electrification for the line and use of electrically powered units

The other options selected for both OOSMs include the following:

- use of the existing rail corridor.
- track configuration is single track with passing loops.
- major upgrade of the existing track in order to achieve 60kph speed limit and above. It is assessed that the system would require four operating units and three passing loops. It is recommended that an additional unit is purchased as a reserve vehicle.
- the track alignment within Hobart would run along the southern side of Davey Street and would connect directly into the rail yard from Davey Street.
- the terminus point in Hobart would be along the waterfront at Mawson Place.
- the recommended signalling system for use of the service is the Electronic Interlocking Signalling System.
- there would be bus interchanges containing provision for three bus stops at Claremont and six bus stops at Glenorchy.
- a park and ride facility with approximately 300 parking spaces would be provided at Claremont.
- a stabling facility for storage of the rolling stock when not in use would be at an existing facility. The rail yard at Macquarie Point could be considered as an option.
- use of existing facilities for control room operations and staff offices.
- a new maintenance facility would need to be constructed with a maintenance pit that would accommodate maintenance operations.

Cost estimates have been developed for the recommended OOSMs as well as indicative costs provided for the options considered. The next stage of this study will calculate the economic costs and benefits associated with these OOSMs.

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1 INTRODUCTION

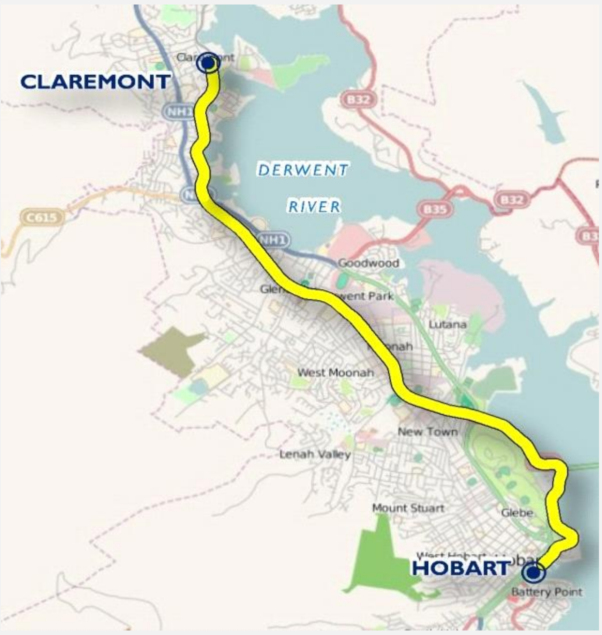

Figure 1: *HLR corridor alignment*

Hyder Consulting Pty Limited (Hyder) has been engaged by ACIL Tasman to form part of the team to deliver the Light Rail Business Case for the Department of Infrastructure, Energy and Resources (DIER). The Hobart Light Rail (HLR) Business Case includes a review of the options and costs associated with the reintroduction of passenger rail to Hobart, Tasmania.

A number of presentations have been made regarding aspects of providing passenger rail in Tasmania. This report provides engineering advice on existing infrastructure and options to form part of the HLR Business Case.

In particular, this report seeks to provide Optimal Operating Service Models (OOSMs) options for introducing a light rail passenger service from Claremont to Hobart. In developing the OOSMs the aim is to consider options for passenger rail that are cost effective, safe and attractive to the community and stakeholders.

Accordingly, this report assesses the condition of the existing freight rail line from Hobart to Claremont. Whilst the freight rail line extends beyond Claremont, this report focuses on the track between these locations as a result of an amendment to the original scope identified in the Stage 1 report prepared by ACIL Tasman. This report is the second stage of the project being delivered by Hyder, ACIL Tasman and SEMF for the HLR Business Case.

- Stage 1 – Background phase, describing the context and setting for the project as a whole and sets parameters for the remainder of the project
- Stage 2 – Is captured in this report and aims to develop OOSMs for a light rail system
- Stage 3 – A report to calculate the economic costs and benefits associated with the OOSMs

Whilst these stages form the HLR Business Case, they are guided by the overarching HLR Feasibility Study which is consistent with the transport planning policies and strategic direction that exists for Hobart and Tasmania.

1.1 Objective

The objective of this report is to provide professional engineering advice and recommendations on OOSMs and service characteristics as part of the HLR Business Case.

To the extent that opportunities and impediments associated with the OOSMs can be identified, they are to be considered. Cost estimates have been prepared for the optimal models identified.

1.2 Scope

The scope of the report includes the following:

- review of existing reports and background information.
- site visit to the existing rail line, Hobart to Claremont.
- prepare options for OOSMs for the rail service to include:
  - determination of existing track adequacy for passenger rail service and level of upgrade required for safe operating track speed.
  - consideration of single track with passing loops or double track.
  - consideration of optimal termination point involving possibility of extending the rail line beyond Hobart Waterfront, Mawson Place to Elizabeth Street. Use of north or south side of Davey Street.
  - consideration of rolling stock available for 1067mm gauge track, in particular use of battery powered units.
  - consideration of electrification.
  - consideration of signalling options.
  - consideration of a maintenance facility and stabling.
  - accessibility requirements compliant with the Disability Discrimination Act (DDA) 1992.
- rail modelling for passenger rail to achieve 15 minute interval rail services and 30 minutes services after 19:00 and on Sundays.
- prepare a cost estimate for the OOSMs for passenger rail.

1.3 Document Review

Prior to commencement of the project, a review of the project background documentation has been undertaken and a list of these reports is included below. The information reviewed has been considered in the development of the OOSMs.

- DIER Southern Integrated Transport Plan, 2010
- Hobart City Council Sustainable Transport Strategy 2009-2014, 2009.
- Hobart and Northern Suburbs Rail Proposal Presentation, Ben Johnston, 25 November 2009
- Battery Rail Vehicles Presentation, Ben Johnston, 2010
- Hobart Northern Suburbs Railway Proposal for Submission to Tasmanian Government's 2010-2011 State Budget, B and K Johnston
- Battery Rail Vehicles, Conference on Railway Engineering, Ben Johnston, 2010
- HLR Cost Estimate: desktop system design and service model Report 1, PB, May 2009
- HLR Cost Estimate: desktop system design and service model Report 2, PB, May 2009
- Future Transport Tasmania, Tasmania Rail – A Vision for Tasmania's Railway Future'
- The Light Rail Business Case, Contextual Background
- Hobart to Northern Suburbs Light Rail Business Case Proposal, ACIL Tasman, 2011
- Hobart to Northern Suburbs Light Rail Business Case, ACIL Tasman, 2011

- Part Three Specification – Hobart to Northern Suburbs Light Rail Business Case, Standard Request for Tender for Services, December 2007
- Answers to Questions from Prospective Tenderers, RFT Number 2065, January 2011
- Answers to Questions from Tenderers, RFT Number 2065, December 2010
- Tasmanian Rail Network Review, Second Track Condition Assessment – Capital and Maintenance Program, Nov-Dec 2007; Asia Pacific Rail (APR), February 2008
- Curve and Gradient Diagrams (South Line), December 2009, Safety Management System, TasRail

2 REPORT METHODOLOGY

2.1 Developing the OOSMs

The report methodology involves a review of the background literature available, a site visit of the rail corridor and consultation with key stakeholders. Based on the information review and engineering analysis, two OOSMs have been developed for introduction of passenger light rail service between Claremont and Hobart. In developing the OOSMs, the following options have been considered:

- track upgrade
- track configuration
- rolling stock
- electrification
- signalling

The options for each of these elements have been analysed in order to derive a set of recommendations aiming to achieve cost effective and reliable solutions that address the criteria set for the introduction of the HLR system.

As part of the OOSM development a specialised rail modelling consultant, Plateway, was engaged to consider the service model options and alternatives by analysing the track alignment including curves, grades, travel speed, travel time, number of passing loops, number of stops and terminus points. A summary of the rail modelling is outlined in Section 6 of this report and a copy of the report is attached in *Appendix B*.

Construction cost estimates have been developed for the OOSMs and for the alternative options. The estimates were developed by Aquenta who provide quantity surveying services. Where costs have been assessed as significantly higher than the alternative options, those options have not been considered in further detail. The construction cost estimates are only indicative and are based on limited information available. The development of the construction cost estimates was intended to provide indicative costs to be used for development of the cost benefit analysis. Details of the estimates are presented in the report from Aquenta enclosed in *Appendix A.*

The information on preliminary patronage demand has been used from the Stage 1 report prepared by ACIL Tasman. These findings have not been checked and verified in this report.

2.2 Study Parameters

The parameters listed below were used in developing the OOSMs. These have been discussed and agreed with DIER during the consultation process held on 14 and 15 April 2011.

- the OOSMs are only considered for the section between Claremont and Hobart.
- the existing rail corridor currently used for freight services is to be used as a rail alignment.
- the existing level crossings that currently have flashing lights are to be upgraded to include boom gates.
- the signalling is to provide a rail service priority at all level crossings.
- the service models need to achieve a 15 minute interval rail service.

- there are five intermediate stops and two terminus points on the route. These are: Hobart CBD; New Town; Moonah; Derwent Park; Glenorchy; Berriedale; Claremont. The infrastructure required at the stops must satisfy the minimum safety and DDA requirements.
- the track gauge to be used if the track is upgraded must remain narrow gauge, same as the existing track gauge.
- the freight service currently using the existing track is expected to cease during 2012. Considerations in this study should not preclude future use of the track for freight and heritage services.

These parameters were used for developing possible optimal models for introduction of light rail in Hobart, in order to produce cost estimates for use in a cost benefit analysis to be completed in Stage 3 of this project. The selection of optimal models including the parameters used, may not represent the final solution for the introduction of light rail in Hobart. During the detailed design stage these would be reviewed and adjusted, based on detailed analysis of the system requirements that would be undertaken prior to implementation of the system.

A risk assessment for the project is included in *Appendix D* details and discusses the risk management approach adopted.

The OOSMs presented take into account considerations that are in line with Australian Standards and comply with rail safety standards.

2.3 Consultation

During the course of the study Hyder met with DIER representatives and various stakeholders. The consultation process and some of the outcomes are described in this section.

2.3.1 DIER

Hyder maintained communication with DIER during the course of the study and met with its Project Management team in April 2011. During consultation the project scope detail was discussed, and the information available and key objectives of the study were agreed.

2.3.2 TasRail

On 14 April 2011, Hyder met with representatives from TasRail, who is the owner of the existing track and the operator of the current freight service. The consultation involved discussion of the track construction, maintenance history, funding and upgrades, and current and future use. During the discussion TasRail indicated that the track is currently used for freight services with only two to three train movements per day. The average speed on the line is 25kph with a maximum speed limit of 45kph.

TasRail indicated that the line in the current condition is not adequate for passenger rail use.

With the development of the Brighton Transport Hub over the next year, it is envisaged that the freight service to Hobart may cease within the next 12 to 18 months.

2.3.3 Hobart Northern Suburbs Action Rail Group

On April 14 2011, Hyder also met with a representative from the Hobart Northern Suburbs Action Rail Group. Similar to the discussion with other stakeholders, the items discussed included the project scope, methodology, use and condition of the existing track and light rail rolling stock options. A description of the track condition raised in the discussion suggested that the track on the northern section of the rail line is in better condition than the track on the southern section, which would require a certain level of upgrade.

2.3.4 Future Transport Tasmania

Hyder met with representatives from Future Transport Tasmania on 14 April 2011 to consult on the project methodology and scope, extent of stakeholder consultation, use of the existing track and the rolling stock options available on the market. These options included new and second hand rolling stock.

3 EXISTING RAIL CORRIDOR

3.1 Site Visit

Hyder attended a site visit of the existing rail corridor between Claremont and Hobart on 15 April 2011. From the consultation process Hyder understood that the existing rail line opened on 01 November 1876 as a narrow gauge single track. The line between Claremont and Hobart was duplicated between 1911 and 1936. Currently the line is a single track with an adjacent cycle path.

The site visit was mainly undertaken in the vicinity of the level crossings and on either side of the level crossings along the full length of the proposed line. The site visit also included the terminus points at Claremont and Hobart CBD. The inspection considered two proposed alignment options between the existing rail yard at Macquarie Point and the terminus point. These included an alignment along Davey Street directly from the rail yard and an alignment from the rail yard through the industrial area into Evans Street before joining Davey Street.

The inspection at the Hobart terminus also considered use of Davey Street for light rail service along the southern and northern side of the street. The terminus point was also considered at the Hobart Waterfront, Mawson Place or extension to Elizabeth Street.

During the site visit Hyder undertook an inspection of the existing rail line between Hobart and Claremont (approximately 15km in length) to assess the general condition of:

- track formation
- drainage
- sleepers
- rail
- structures
- alignment
- level crossings
- adjacent areas

The assessment of the track condition in this report was based on the site visit undertaken on the 14 and 15 April 2011. The following information was also used in establishing the overall assessment of the condition:

- existing reports and records and track data such as current speed limit, curve radii and grades.
- information received during consultation with TasRail and other stakeholders.
- Tasmanian Rail Network Review – Second Track Condition Assessment Report Nov-Dec 2007 Capital and Maintenance Program undertaken by APR, February, 2008.

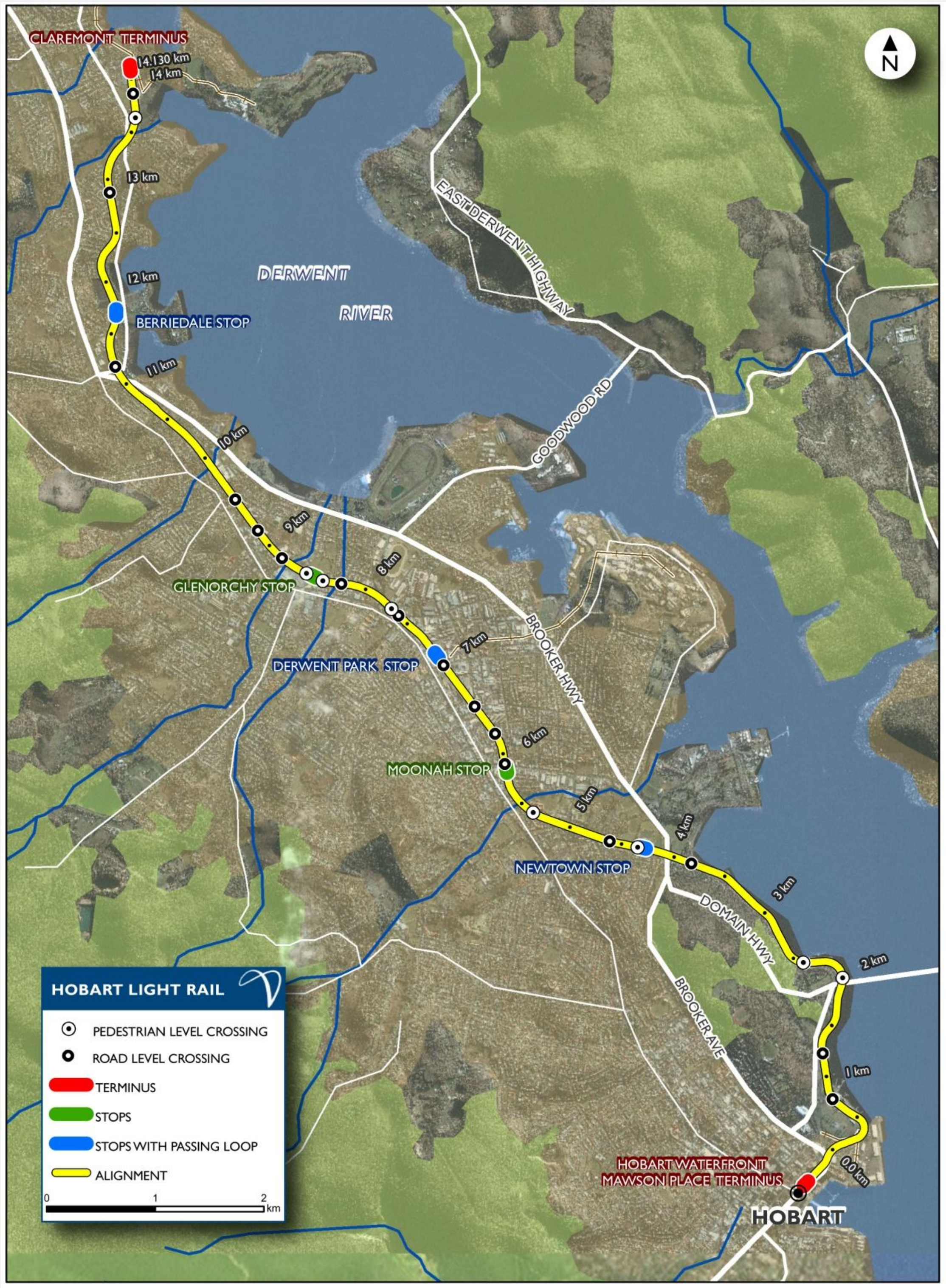

Figure 2: *Hobart Light Rail – proposed alignment information*

3.1.1 Track Condition

Track condition was assessed visually through site inspection by the experienced Hyder team. Detailed information was also received through discussions with the TasRail representatives.

The issues identified during the inspection are discussed in further detail below.

Formation

The typical track formation design consists of the ballast below the sleeper supported by capping material, as shown in Figure 3. The capping layer comprises a layer of compacted material that provides a sealing layer to the earthworks.

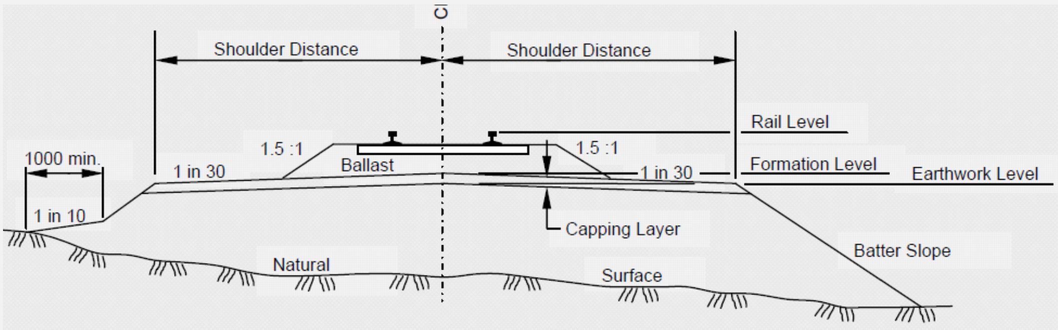

Figure 3: *Typical single track cross section*
(source: RailCorp Engineering Manual – TMC 411 Earthworks ver. 2.0 July 2010)

The track formation was in general considered to be poor as there were areas with very little or no ballast. In some areas that contained ballast it was evident that the ballast was fouled and contained soil and sand. The ballast on certain sections of the track was in reasonable condition.

Drainage

The success of any track is governed by its effectiveness in draining water from the ballast above the capping and from the subsoil beneath the capping. Poor drainage will cause the track formation to become saturated, leading to weakening and subsequent failure.

For the existing line, the drainage can be generally described as poor and some sections appeared to have no drainage. The lack of ballast or the presence of fouled ballast does not allow water to freely drain from the track, which has caused the deterioration of the timber sleepers, resulting in the rail not being adequately supported in some locations.

Sleepers

The track includes a combination of concrete, steel and timber sleepers. Concrete sleepers were noted at the recently upgraded sections inspected near level crossings, as shown in Photographs 1 and 2. The combination of the sleepers does not represent a problem in terms of track integrity, if the sleepers are in good condition. From an ongoing maintenance perspective however, the concern becomes more recognised as different types of sleepers deteriorate at different rates.

It was noted that the rail corridor contained a significant percentage of 'rotted' timber sleepers, typically as shown in Photograph 3. These 'rotted' sleepers were not supporting the rail resulting in more stress being placed on the surrounding sleepers and rail.

On occasions, it was difficult to assess the state of the sleepers in areas as they were either partially or completely covered ballast. For the purpose of this study, comprehensive and detailed assessment of the integrity of these sleepers was not required.

Evidence of track pumping, as shown in Photograph 4 was also prominent. At these locations the sleeper is only supported by mud resulting in the vertical movement of the rail and inadequate support to the rail and the services using the line.

Rail

The rail in-situ for most of the route length is 41kg (41kg of steel per meter length) rail. This is considered suitable for Light Rail Vehicles (LRV).

It was also noted that there were missing or broken rail clips, meaning that the rail was not securely fastened to the sleeper.

Although it was not observed during the inspection, it was noted in the Tasmanian Rail Network Review – Second Track Condition Assessment Nov-Dec 2007 Capital and Maintenance Program (APR, 2008), that a section of the corridor contains a buckle. The remedy for this will be to replace the section of track.

The report also highlighted sections of the track that are worn, particularly on the tighter curves. These sections will require rail grinding works to occur or potentially sections of rail to be replaced.

Photograph 1: *Combination of timber and steel sleepers (source: Hyder 2011)*

Photograph 2 – *Combination of steel and concrete sleepers (source: Hyder 2011)*

Photograph 3 – *Condition of timber sleepers (source: Hyder, 2011)*

Photograph 4 – *Track pumping (source: Hyder, 2011)*

Structures

The bridge structures visually inspected along the track are considered to be in reasonably good condition. An allowance has been made in the cost estimates for upgrading the bridge crossing near Wrights Avenue, Glenorchy. The visual assessment provides only a basic overview of the bridge condition which was used for provision of an indicative cost estimate of the bridge upgrade required.

Alignment

Based on the information supplied to Hyder by TasRail, the corridor comprises some tight curves at certain locations that would necessitate lower speed limits.

To maximise speed and therefore minimise travel time, the curve radius could be increased or straightened by undertaking re-alignment works of the existing track. This was not considered in detail due to the high cost of constructing an alternative alignment.

Grade Crossings – Road

During the meetings held on 14 and 15 April 2011, DIER advised that all level crossings will be upgraded as part of the HLR introduction to include boom gates as a minimum. Should the HLR project proceed, it is highly recommended that the operation of all level crossings for passage of LRV is checked and certified.

An assessment of the area in and around the crossings was made. The track and drainage conditions were inspected at each level crossing approximately 100m in both directions.

Table 1 lists the level crossings inspected during the site visit. Each crossing is controlled by flashing lights and bells.

Table 1: Level Crossings Inspected

CROSSING NO.	LOCATION
01	McVilly Drive
02	Queens Walk
03	Bay Road
04	Albert Road
05	Hopkins Street
06	Sunderland Street
07	Derwent Park Road
08	Lampton Avenue
09	Elwick Road
10	Wrights Avenue
11	Grove Road
12	Riverway Road
13	Berriedale Road
14	Myella Drive
15	Box Hill Road

The heavy axle loads of the freight rail traversing the intersections have caused movement of the rail within the road and pedestrian crossing sections, which in turn has deteriorated the road surface (Photograph 5) and presents a hazard to pedestrians and cyclists traversing the crossing areas.

In addition to the above vehicle level crossings there are a number of pedestrian crossings situated along the rail corridor.

Photograph 5 – *Track at level crossing (source: Hyder, 2011)*

The condition of these crossings will require further assessment to ensure that they comply with the relevant rail safety standards. In addition, as LRVs could be travelling at speeds of up to 60kph, there may be a necessity to provide a warning system at the crossing for oncoming LRVs.

Adjacent Areas

During the inspection, it was noted that the cycle path runs in parallel and in close proximity to the rail line. The cycle path provides an opportunity for introduction of a second rail track. Should it be determined that a second track is required, further detailed analysis should be conducted to determine space availability for clearance requirements.

Based on a visual inspection of each of the proposed passenger platform locations, there appeared be sufficient room for platform structures and passing loops, with the exception of New Town. The space at this location is restrictive and also has a slight gradient. If a passing loop is required for this location, as determined by the timetable simulations, then the passing loop and stop should be on the southern side of the rail bridge where sufficient space is available.

3.2 Summary

Hyder assessed that the existing track formation has deteriorated over time as a result of minimal maintenance. The track condition is poor and is deemed inadequate for passenger rail traffic use with a maximum speed of 60kph, without substantial improvements.

The level of upgrade has a direct correlation with the maximum speed of the rolling stock.

The Tasmanian Rail Network Review – Second Track Condition Assessment Nov-Dec 2007 Capital and Maintenance Programs undertaken by APR also assesses the track condition as poor (February, 2008).

The inspection also concluded:

- there is sufficient room at the proposed stop areas for passenger platforms
- the existing line is currently in use and therefore is trafficable with a maximum speed of 45kph and an average speed of 25kph
- a suitable location at Hobart waterfront near Hobart Waterfront, Mawson Place is available for a terminus that will present no interruption to Davey Street and will potentially enhance the waterfront area and attach pedestrian movement
- there is a suitable location for the Claremont terminus with no interruption of the existing line

4 OPTIMAL OPERATING SERVICE MODELS

4.1 Criteria

Hyder has assessed the following criteria in developing the preferred OOSMs that will deliver the required 15 minute interval service level.

The criteria assessed were:

- track configuration
- track upgrade
- electrification
- signalling
- rolling stock
- maintenance facility

Rail modelling was also performed to determine the requirements for delivering the agreed level of service and in developing the two OOSMs and recommended alternatives to be considered.

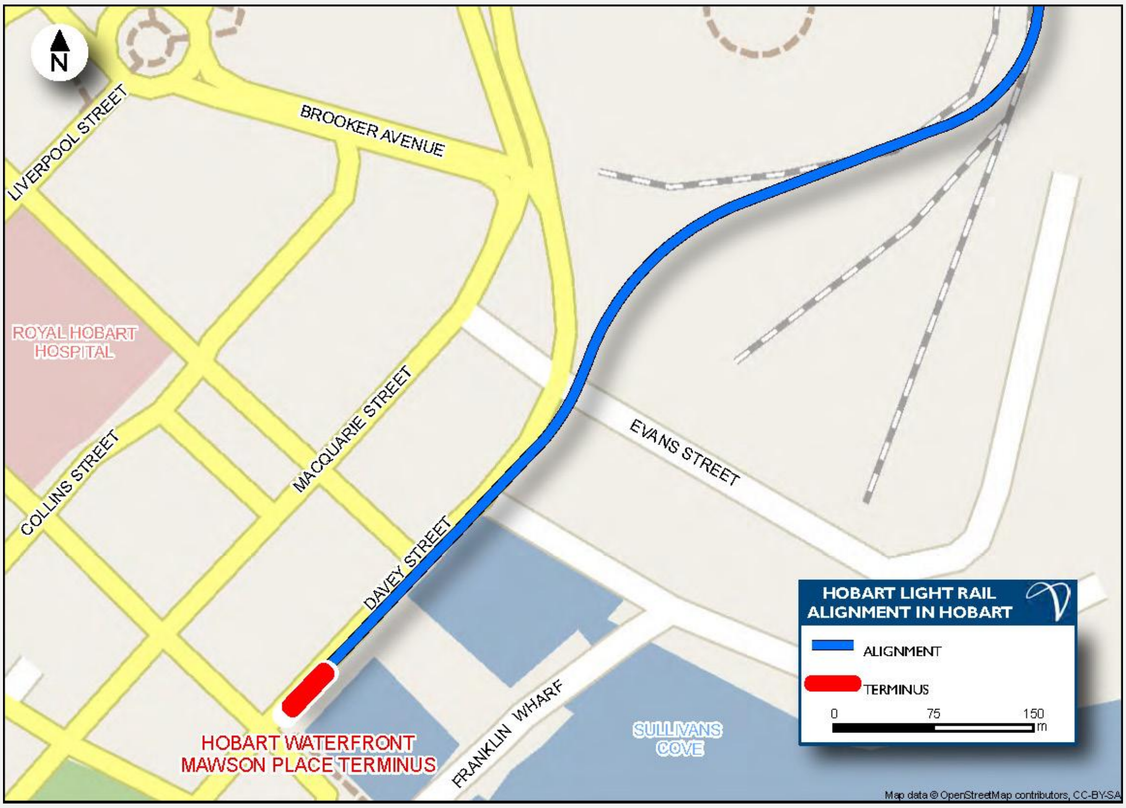

Figure 4: *Proposed rail alignment Hobart CBD*

4.2 The OOSMs

The two optimal models and the recommended alternatives for further consideration are listed below. The variable used in the development of the OOSMs is the use diesel powered units as rolling stock or provision of electrification for the rail line and use of electrically powered units.

OOSM 01	*Use of diesel for rolling stock,* major track upgrade to achieve 60kph speed limit and over, connection from rail yard directly to Davey Street, provision of a bus interchange and a park and ride facility, maintenance facility and stabling, single track with passing loops, terminus at Hobart Waterfront, Mawson Place, travel on south side of Davey Street, electronic interlocking signalling system
OOSM 02	*Electrified rail line with use of electrically powered units,* major track upgrade to achieve 60kph speed limit and over, connection from rail yard directly to Davey Street, provision of a bus interchange and a park and ride facility, maintenance facility and stabling, single track with passing loops, terminus at Hobart Waterfront, Mawson Place, travel on south side of Davey Street, electronic interlocking signalling system

4.2.1 OOSM 01

Rolling Stock Diesel Units

Use of modern Diesel Light Rail (DLR) vehicles allows for flexibility in operations and reliability with a well established history of use.

Modern DLR incorporate low floor, are efficient, quieter, accelerate faster and more smoothly and produce less emissions. Many of the modern vehicles are able to run on bio diesel fuel.

Some of the examples and possible options for use of the DLRs include

- Bombardier O-Train
- Stadler GTW 2/6
- Regio Citadis or Citadis Dualis

With the development of the battery powered units it is envisaged that in the future the use of diesel units may be replaced with battery powered units. The alternative option to be considered for the future is also installation of overhead traction power.

The rolling stock options have been described in further detail in Section 5 Development of OOSMs.

4.2.2 OOSM 02

Overhead Wires (OHW) Electrification of the Rail Line

This is the most common system for powering LRVs. Conductor wires are supported directly on masts adjacent to the track or head span wires attached to masts. Conductor wires are sometimes supported by catenary wires that also carry current and are in turn supported on structures that can be more widely spaced than directly supported conductors. Whilst some support structures tend to be rather utilitarian, careful design can result in very elegant solutions.

Generally the installation of an overhead wiring system attracts a high capital cost in comparison to use of diesel powered rolling stock. However due to the large variance in the rolling stock price which is highly dependent on the availability on the market at the time of purchase, this system may not be as expensive as it may initially seem. One of the advantages of this system is that it is the most commonly used system and the rolling stock options would be wider than the diesel unit options.

4.2.3 OOSM Common Elements

Major Track Upgrade

In order to achieve 60kph speed limit and over, for use of passenger traffic, the track requires major upgrade.

The work would involve removal of the track structure, compact the existing formation, construct approximately 150mm capping layer, clean and reuse existing ballast where appropriate and add new ballast, place new or second hand concrete sleepers and top up with ballast. After levelling the ballast with the top of the sleepers installation of new or second hand serviceable rails welded and fasten to the sleepers with Pandrol Clips would be required. Some of the existing rail that is in good condition could be reused. After completion of the track installation, tamping and levelling of the track would be required.

This option would require three passing loops and four rolling stock units to achieve the 15 minute interval services. It is recommended that an additional unit is considered as a reserve and used during maintenance or failure of the operating units.

The rail modelling completed for this study shows that with a speed limit of 60kph, a diesel powered unit would achieve approximately 23 minutes travel time between Claremont and Hobart. This system would require five operating units to achieve 15 minute interval service. The modelling shows that a 22 minute travel time is required to enable four units to achieve a 15 minute interval service. Therefore for the purpose of this study and based on the theoretical speed of the line being 70kph, it is assumed that with major upgrade of the track a speed limit of 65kph would be achieved allowing 22 minute travel time and reducing the number of units to four. It is recommended that an additional vehicle is purchased as a substitute during maintenance or breakdowns of the operating units. The additional vehicle would improve the reliability of the operating system and would increase the capacity during peak periods should it be required.

Connection to the Rail Yard

In the optimal models it is proposed to connect the rail line from the terminus continuing along the footpath of Davey Street on the southern side passing adjacent to the end of Hunter Street and crossing Evans Street at level before joining the alignment at the existing rail yard. An additional level crossing will be required at Evans Street.

Bus Interchange and Park & Ride

The optimal models will incorporate a bus interchange near Claremont and Glenorchy stops.

The bus interchange with six adjacent bus stops will be provided at Glenorchy and three bus stops at Claremont. The bus stops will consist of lit shelters, hardstand area, DDA access and seating.

A park and ride facility will be introduced at Claremont that will accommodate 300 parking spaces. The park and ride facility will be constructed as an asphalt pavement with adequate signage and linemarking.

Existing Stabling Facility and New Maintenance Depot

The optimal models assume use of an existing facility for stabling the rolling stock when not in use. The rail yard at Macquarie Point has been used as a potential option, although it may not be available. The yard would require two to three roads with an approximate length of 100m each. This would provide savings in constructing a new stabling yard facility with adequate fencing and security. It is also assumed that the existing offices at the rail yard would accommodate an office area space for the operations of the light rail system.

It has been assumed that a new maintenance facility would need to be constructed for maintenance of the rolling stock. The new maintenance depot would require a portal frame structure over a single road and a maintenance pit that would accommodate specialised equipment for maintenance of the rolling stock. An area near Montrose could be considered as an option for construction of a new depot or Macquarie Point. The cost estimates developed do not make allowance for land acquisition should it be required for constructing a facility.

Single Track with Passing Loops

The optimal models require a single track with a minimum of three passing loops and minimum of four units to achieve the required 15 minute interval service level. The number of passing loops and light rail vehicle units required is dependent on the level of upgrade of the track and the speed limit.

Many rail systems around the world operate where rail vehicles work in either direction over a single line. Rail vehicles which run in opposing directions pass each other at designated locations where passing loops are available, Figure 5.

At each passing loop, a point switching mechanism is employed to set the vehicle path. The point switch mechanism can be mechanical, lever operated or electromechanical device.

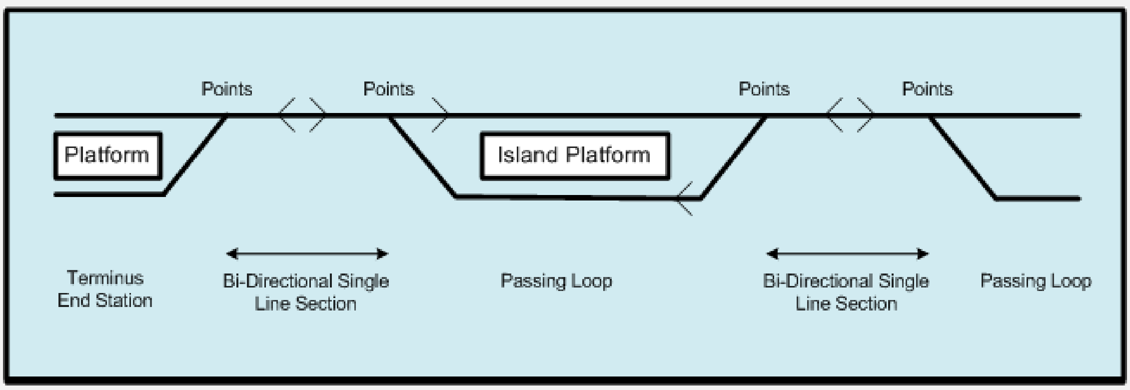

Figure 5: *Single line configuration*

Ideally the passing loops will be located at the passenger pickup platforms, however based on the number of LRV, the LRV intervals and distances, their positions may not necessarily align. These variables form part of the modelling scenarios which are considered in Section 6 and *Appendix B.*

The following highlights some of the advantages / disadvantages of a single line system:

ADVANTAGES	DISADVANTAGES
▪ Majority of rail infrastructure currently in place ** ▪ Less rail maintenance required	▪ Crossing loops required ▪ Additional equipment, point machines required at each passing loop ▪ Signalling system is more complex ▪ Potential delays at cross points as LRV heading in one direction cannot proceed until the opposing LRV arrives and clears the section ahead. The will be exacerbated if the opposing LRV is delayed.

*** Does not consider the current state of the rail infrastructure and the works required to bring this to a suitable level for operation of passenger rail vehicles*

Terminus at Hobart Waterfront, Mawson Place / South Side of Davey Street

The following intermediate stops and terminus are proposed on the alignment of the Hobart Northern Suburbs Railway, section from Hobart CBD to Claremont:

1 Hobart Waterfront, Mawson Place, Hobart – terminus

2 New Town – intermediate stop (passing loop)

3 Moonah – intermediate stop

4 Derwent Park – intermediate stop (passing loop)

5 Glenorchy – intermediate stop

6 Berriedale – intermediate (passing loop)

7 Claremont – terminus

Photograph 6 – *South side of Davey Street, north east of Hobart Waterfront, Mawson Place (source: Hyder, 2011)*

The terminus at Hobart Waterfront, Mawson Place Hobart CBD is proposed on the southern side of Davey Street in the footpath area and not affecting the road traffic, refer photograph above.

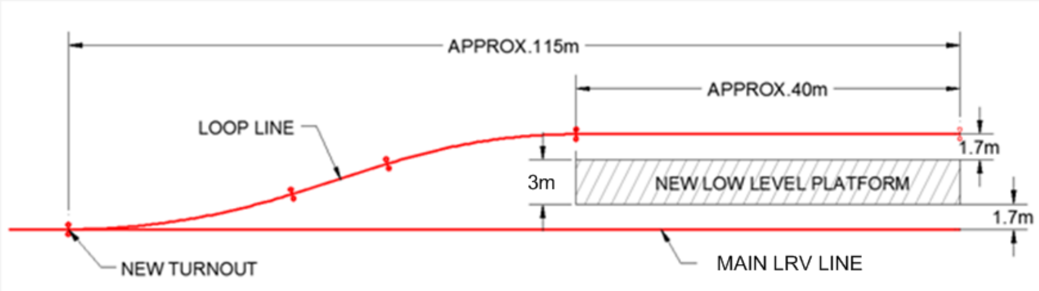

Figure 6: *Schematic Track Diagram for the Terminus at Claremont*

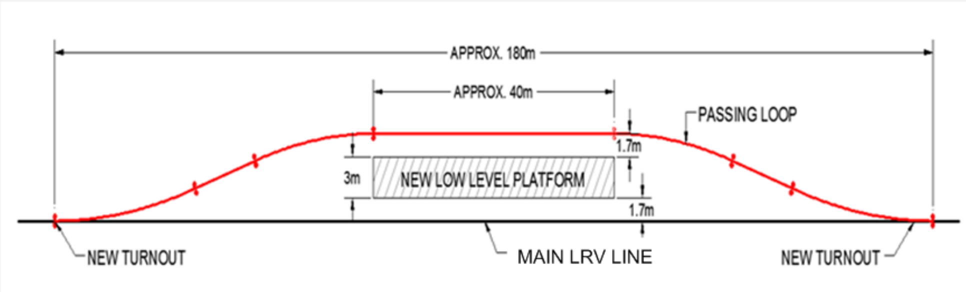

Figure 7: *Schematic Track Diagram for Intermediate Stop and Passing Loop*

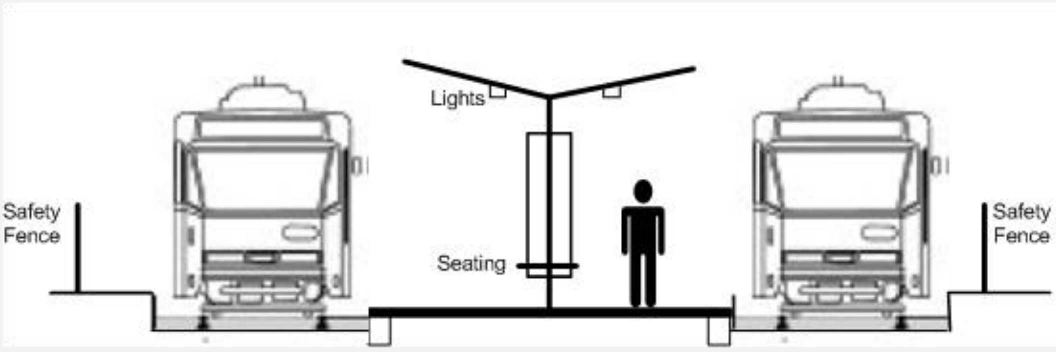

Figure 8: *Passenger Stop – Indicative Cross Section*

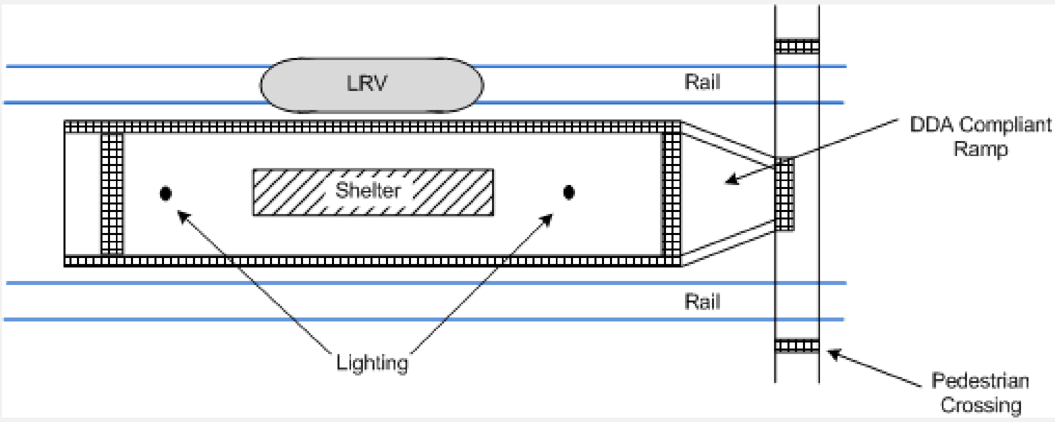

Figure 9: *Passenger Stop – Indicative Plan View*

Signalling – Electronic Interlocking Signalling System

The optimal models consider use of the electronic interlocking signalling system. This type of system is flexible and can be configured for simple driver control application or to the higher end of dispatcher control (control centre). This system provides various advantages in comparison to the train order system which is the alternative that has been considered and is described further in Section 5.

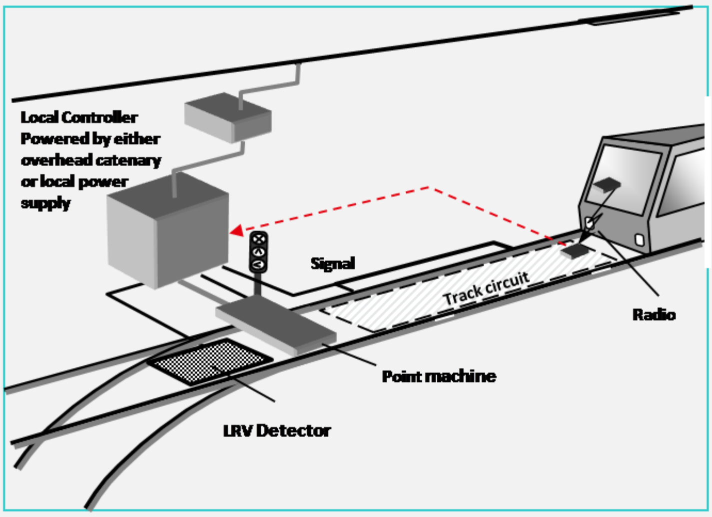

Figure 10: *Electronic interlocking signalling system*

The basic principle of this type of system is

- As LRV approaches the turnout, it sends the system a command to set the points to the required path should the section not occupied by another LRV.
- After the points are secured (locked), the signal changes aspect to allow the driver to proceed across the points and into the next section (next signal).
- The points will automatically restore to normal position (main line) following movement of LRVs across the points.

- The system has the following properties:
- LRV detection is based on fail-safe track circuits and inductive loop mass detectors.
- Local point switch control from an approaching LRV (via on board radio transmitter).
- A central interlocking system communicates (by radio) with each of the remote object controller units to set/clear line blocks into sections.
- Power can be derived from the overhead catenary.

This system does not require a controller/dispatcher as does the Train Order System and therefore is not dependent upon the interaction and exchange of information between the two. However it does require trackside equipment to be installed and maintained.

Ticketing

For the purpose of the report it has been assumed that the ticketing used on the light rail system would be an extension of the existing system which would be implemented with a relatively low cost in comparison to the overall cost of the light rail introduction.

4.2.4 Other Alternatives to be Considered in Addition to the OOSMs

Partial Track Upgrade

In order to achieve 45kph speed limit for use of passenger traffic, the track requires partial upgrade. The partial upgrade would involve undertaking works as per the major upgrade option for certain sections along the rail corridor that have significantly deteriorated. This would involve removal of the track, compaction of the subgrade, introduction of a capping layer, placing of new or reused ballast, placing second hand or new concrete sleepers and top up with ballast and placing the rail either reused, second hand or new.

Part of the track that is in better condition would be upgraded by removal and replacement or reuse of the ballast and sleepers and rail. These sections would use the existing subgrade and no capping layer will be placed. The rest of the track that is deemed to be in reasonable condition will be reused with minor work at location of defects.

The maintenance cost of this option over the first five years of operation would be significantly higher than the maintenance cost of a fully upgraded track.

This option would require four passing loops and five rolling stock units to achieve a 15 minute interval services. It is recommended that an additional unit is considered as a reserve and used during maintenance or failure of the operating units.

Extension of the Line to Elizabeth Street, south

Figure 11: *Proposed alternative rail alignment Hobart CBD*

It is recommended that an extension of the railway line Argyle Street south of Davey Street to Morrison Street and turning right into Elizabeth Street with a termination point just south of Davey Street is considered as an alternative to the terminus at the Waterfront, Mawson Place. This would provide the benefit of the light rail travelling closer to the CBD and in sight distance of the bus interchange further north on Elizabeth Street. The capital cost of the extension would not increase significantly if the provision of terminus point is provided at this point instead of at Mawson Place.

Traffic disruption would also be minimal as there is an indication of low traffic volumes using Elizabeth Street south of Davey Street.

The proposed alternative will increase the section travel time and an additional unit may be required. A passing loop will need to be located in the rail yard at Macquarie Point.

Use of the Train Order System

As an alternative to the electronic interlocking signalling system it is proposed that the train order system could be used. The advantage of the Train Order System is the low capital cost with minimal infrastructure requirement. This system can be replaced at a later stage when the demand of the rail line increases. However this system would provide higher operating costs.

5 OPTION CONSIDERATION IN DEVELOPMENT OF OPTIMAL OPERATING SERVICE MODELS

This section describes the options that have been considered in development of the OOSMs. The following table summarises the option considerations under each of the criteria.

Table 2: The options considered in development of OOSMs

ELEMENTS CONSIDERED		OPTIONS		COMMENTS
1	Track Upgrade	1.1	Major Track Upgrade	In order to achieve 60kph speed limit the track would require major track upgrade. Same alignment will be maintained.
		1.2	Partial Track Upgrade	In order to achieve 45kph speed limit for passenger service partial upgrade of the track is required, estimated at approximately 50 to 60% of the track to be upgraded.
		1.3	Minor Track Upgrade	Sections with major defects to be rectified. Assessed as 10% of the track to be upgraded. This would include changes of all rotten timber sleepers, replacement of some rail fastenings and cess drain clearing. This would allow passenger service to run with a speed limit of 25 to 30kph.
2	Track Configuration	2.1	Single Track with Passing Loops	Use of the existing track.
		2.2	Double Track	Replace existing shared path with double track and relocation of the shared path.
3	Track Alignment, Hobart	3.1	From Rail Yard Directly on Davey Street	From Rail Yard at Macquarie Point directly onto Davey Street.
		3.2	Through Industrial Area, along Evans Street Davey Street	From Rail Yard through the industrial area to avoid future contaminated land remediation works.
4	Terminus Point in Hobart	4.1	Hobart Waterfront, Mawson Place	
		4.2	Elizabeth Street	Via Morrison Street to south of Davey Street.
		4.3	Elizabeth Street	Via Morrison Street to north of Davey Street.
		4.4	Elizabeth Street	On Davey Street up to Elizabeth Street.
5	Davey Street	5.1	Northern Side	
		5.2	Southern Side	

ELEMENTS CONSIDERED		OPTIONS		COMMENTS
6	Rolling Stock	6.1	Diesel Powered Units	Diesel Multiple Units (DMU).
		6.2	Electrical Units	Overhead power supply.
		6.3	Mechanical Energy Storage	
		6.4	Electrical Energy Storage	Battery powered units.
7	Signalling	7.1	Electronic Interlocking Signalling System	
		7.2	Train Order System	
8	Electrification	8.1	Overhead Traction Power	
		8.2	Non Electrified System	
9	Maintenance Facility	9.1	Stabling Yard and Maintenance Facility	It is assumed stabling can be provided at an existing facility and a new maintenance depot will need to be constructed.

5.1 Track and Alignment

Technical information about the existing rail corridor is contained in *Appendix C* where tabled information shows the existing track alignment parameters as provided by TasRail. The second table shows design criteria for the rail line required to achieve speed limit of 60kph.

5.2 Track Upgrade

In total, three options of track upgrades were considered for development of the OOSMs. In addition to the two options described in Section 4 OOSM the third option included minimal upgrade of the track where significant defects are identified. With this option it is assessed that a maximum speed limit of 25kph to 30kph would be adequate for use of passenger rail services.

The current speed limit of the rail corridor for the existing freight service is 45kph. With the introduction of a higher frequency services on the line and in particular the introduction of a passenger rail traffic with greater consequence of any safety risk, in order to maintain the safety levels the speed limit would require reduction to 25 to 30kph. The lower speed limit would also improve the ride quality.

This option was not considered as optimal due to: the slow travelling speed and the travel time required to travel between Claremont and Hobart; the increased number of loops and the large number of units that would be required to run a 15 minute interval rail service. This option would also require significant maintenance costs for the corridor in order to maintain a passenger rail service and potentially higher maintenance costs for the rolling stock.

5.3 Track Configuration

As part of the OOSM development, the introduction of a second track was considered adjacent to the existing track. The new track would replace the existing cycle path facility which runs parallel to the existing track for most of the route length. The construction of the new track would require relocation of the existing cycle path facility. For most of the line this can be accommodated along the side of the track but would require alterations of the existing infrastructure in particular near the overbridges and underbridges.

At some locations alternative solutions may need to be sought in order to avoid significant capital cost for infrastructure alterations. An example of this is the section near New Town north of the Bay Road level crossing.

Provision of a double track would provide various benefits for the introduction of rail passenger services. Some of these include reduced safety risks, simpler signalling system and improved reliability with a reduced risk of delays caused by one vehicle impacting on other services.

The capital cost for introducing a double line would however be significantly higher than use of a single line with passing loops. Additionally the maintenance costs of the second track would also be higher, therefore the introduction of a double track was not considered to be an optimal option in the OOSMs.

5.4 Track Alignment

As part of the OOSM development the use of the existing corridor has been considered as most adequate. Use of an alternative alignment would impose significant infrastructure and land acquisition costs and was therefore deemed inappropriate for use in the OOSMs and has not been considered in detail.

In addition to the recommended optimal option of the alignment connecting the rail yard to the Hobart terminus point directly onto Davey Street, an alternative alignment was considered through the industrial area and Evans Street, as proposed by Hadley Sides, in an email received from DIER on 13 April 2011.

The alignment through the industrial area is longer, it introduces light rail vehicle street running along Evans Street and there are two sharp curves of 90 degrees which will impact on the travel time. The infrastructure modification along the long term port boundary seems to be greater than the alternative. Although it is understood that the proposed optimal alignment may run through a future contaminated soil remediation area this option is deemed not to be optimal at this stage. If the alternative alignment is deemed more appropriate for the long term plan, there is a potential for the alignment to be altered at the later stage as part of future redevelopment of the area.

5.5 Alignment on Davey Street

In consideration of the rail alignment along Davey Street the following advantages and disadvantages were considered.

Northern Side of Davey Street

Crossing a major arterial road would require a signalised intersection and would create disruption to road traffic. Due to the insufficient space on the northern side of Davey Street the road traffic lanes may require relocation to the south to maintain the same road traffic capacity and provide sufficient space for the rail. This would mean reduction of the footpath area on the south side of Davey Street to accommodate relocation of the road traffic lanes. The cost for the infrastructure modifications would be higher than the cost for modifications of the southern side of Davey Street. Alternatively the LRV could travel in the traffic lane but this would cause traffic disruption and would reduce the road traffic capacity. Traffic analysis would need to be undertaken to determine the extent of disruption that would be caused.

Southern Side of Davey Street

Use of the southern side of Davey Street is deemed as optimal as there is no conflict with road traffic movements. The footpath area at Hobart Waterfront, Mawson Place provides sufficient space for the introduction of a terminus point without major infrastructure modifications and the integrity of the pedestrian area along the waterfront will be maintained. The introduction of a terminus point on the south side would be lower in cost than introducing it on the northern side of Davey Street. It is also likely that the introduction of the light rail at the Hobart Waterfront would help activating the area and attracting higher patronage use, by introduction of an elegant and modern design.

5.6 Terminus Point in Hobart

As part of the optimal model the Hobart Waterfront at Mawson Place was selected as a terminus point for the first stage of the implementation. An extension of the rail line on Elizabeth Street with a termination point south of Davey Street, through Morrison Street, has also been considered as a viable solution.

Other options considered with regards to an extension of the line within Hobart include:

- extension on Davey Street up to Elizabeth Street
- extension to Elizabeth Street and north along Elizabeth Street up to Macquarie Street
- extension to Elizabeth Street at the intersection with Morrison Street and along Elizabeth Street to Macquarie Street

Although some or all of these options would provide benefits, they have not been considered as optimal due to the increase in capital and operating cost, disruption to road traffic or significant increase in travel time between Claremont and Hobart.

5.7 Rolling Stock – Light Rail Vehicles

The selection of the right vehicles for a LRV network is fundamental to success of the system.

This is as true for the start-up as it is for the future development of the network. In this regard Hobart Light Rail (HLR) provides some challenges, constraints and opportunities.

An overarching consideration of the entire system is initial capital cost, which must be kept low enough to ensure financial feasibility in the early stages of the project, yet not be so ‘basic’ as to detract from usage of the system, or be obsolescent within a few years of opening. One way of approaching this is to ensure that the initial system is, as far as is practical, upgradeable as the service develops with minimal wastage.

This approach must be kept strongly in mind when considering the selection of rail vehicles.

5.7.1 Rail Gauge

One early consideration which will set the direction for selection of vehicles is that of rail gauge. The existing rail gauge in Hobart is a Narrow Gauge (1067mm).

As mentioned elsewhere in this report much of the proposed initial stage of the HLR will be along the existing Narrow Gauge line north of Hobart. The track on this line is in poor condition and it is recommended elsewhere that it be replaced. The current recommendation is that this track be replaced in Narrow Gauge to, amongst other things, enable compatibility with heritage vehicles and enable freight to continue to use the line in the immediate and mid future.

Other tram and LRV Systems around Australia, being Melbourne, Sydney and Adelaide are Standard Gauge.

One argument for adopting Standard Gauge is the wide choice of vehicles that it opens up on the basis of the majority of systems around the world that use Standard Gauge Light Rail Vehicles, however many systems, particularly in Europe, use 1000mm gauge, and many modern vehicles are available for this gauge and could be relatively easily modified to 1067mm gauge.

It is recommended that 1067mm gauge be maintained for the HLR.

5.7.2 Floor Height

Ease of use and ‘people friendliness’ has been an important consideration in the design of modern LRV, as has the need to accommodate access requirements. This is particularly significant in street running sections where high platforms and their attended long ramps are a visual and practical intrusion in busy city streets. This has led to the development initially of vehicles with partial low floor (350mm), normally in the centre of the vehicle, with steps to higher floor sections over the drive wheels and motors. An improvement in the technology of Cardan Shaft Drives and Stub Axles has now enabled full low floor vehicles to be economically achieved.

Whilst the current stage of HLR is primarily open running on dedicated track with reasonable space around the stops, some of it involves street running and any extension in the future would almost certainly involve shared street running.

For this reason it is recommended that preference be given to vehicles that have at least partial low floor, so as not to introduce possible obsolescence.

The only circumstance where this recommendation might open to reconsideration is if particularly inexpensive good quality second hand vehicles become available. In which case ‘temporary’ platforms or hobs could be constructed at all stops.

5.7.3 Traction Power

The majority of Light Rail Systems around the world operate on some form of Overhead Wire (OHW) electrification, usually between 600 and 750 VDC, although many other electrical or diesel powered options have been used for many years, and there are some exciting and promising new systems under development.

The various Traction Systems can be categorised as follows:

- OHW Electrification
- Non OHW Electrification
- Electrical Energy Storage
- Mechanical Energy Storage
- Diesel Power

These categories and their applicability to HLR requirements are discussed below, along with their advantages and disadvantages.

OHW Electrification

This is the most common system for powering Light Rail Vehicles. Conductor wires are supported directly on masts adjacent to the track or head span wires attached to masts, or now less commonly to buildings. Conductor wires are sometimes supported by catenary wires that also carry current and are in turn supported on structures that can be more widely spaced than directly supported conductors. Whilst some support structures tend to be rather utilitarian, careful design can result in very elegant solutions.

Photograph 7 – *OHW Electrification Citadis OHW power (source: Alstom)*

Transformer/rectifier stations are required at regular intervals along the route. Modern OHW powered vehicles use AC drive motors with efficient GTO Chopper control and rooftop inverters to convert the DC to AC. Energy-saving regenerative braking is common in modern vehicles of this type.

Typical modern examples are Citadis 202 and 302 vehicles operating in Melbourne and Adelaide, and Bombardier Variotrams operated by Sydney Light Rail, which operate at 600VDC and 750VDC respectively.

ADVANTAGES	DISADVANTAGES
▪ Simple well-proven system ▪ Sustainable, particularly with the use of 'green' energy ▪ Ease of control	▪ High initial cost ▪ Overheads can be seen by some as visually intrusive ▪ Stray currents need control

With application to HLR the major issue is cost. As stated above, the objective is to establish a viable system with the lowest initial capital cost, and add enhancements as patronage improves.

Non OHW Electrification

Non OHW Electrification has operated on metro and heavy rail systems around the world for many years, generally in the form of 'third rail' electrification. For safety reasons this is not appropriate for Light Rail because of the open nature of the track and reservation.

However, over recent years systems have been developed that collect power from within the track either direct contact with embedded third rail or by using induction pads installed between the rails.

Photograph 8 – *Citadis APS in-track power, Bordeaux. (source: Alstom)*

These differ from traditional third rail in that the power is only switched on when the LRV is directly above that section of rail or the particular induction pad, ensuring safety for pedestrians and road users.

An example of embedded third rail is Alstom's APS system which has been operating in Bordeaux since 2003 on 14km of the 44km network.

Bombardier has an inductive power pick up system under development with a short section installed in France.

ADVANTAGES	DISADVANTAGES
▪ Visually unobtrusive, compared with OHW ▪ Highly suited to heritage precincts	▪ Very high cost ▪ Technology not well established

Electrical Energy Storage

These systems immediately break down into those using batteries and those using super capacitors, to store the traction energy.

Battery powered rail and road vehicles have been in use for over 100 years, early examples using traditional lead-acid batteries and more recent examples using more modern nickel-metal hydride batteries. A renewed interest in electric cars has spurred further considerable development of batteries to improve their energy density and decrease charging time.

Photograph 9 – *Kinkisharyo Ameritram (Source: Kinkisharyo)*

A number of LRV manufacturers have developed and are improving battery powered and hybrid traction systems. To date, the stated primary use of these systems is to eliminate OHW over sections of the network, particularly where heritage considerations prevent or discourage the use of OHW. A well documented example is in Nice, France where Alstom Citadis LRVs are able to run up to 1km on battery power, before returning to the OHW to seamlessly recharge.

Photograph 10 – *SWIMO Battery Powered Vehicle, Japan (source: Kawasaki)*

Another is the SWIMO vehicle under intense development by Kawasaki Heavy Industries. The SWIMO vehicle uses specially developed batteries and direct regenerative braking to optimise battery operation and can travel 10km before recharge under test conditions. Whilst the development vehicle is small, accommodating only 28 seated passengers, the concept is modular and can be grouped to enable larger capacities. The initial vehicles have been built in Narrow Gauge, but it is not clear if this is 1000 or 1067. Unlike the Nice example, the SWIMO operates in continuously in battery mode and is not connected to OHW, relying instead on opportunistic charging at stops and termini.

ADVANTAGES	DISADVANTAGES
▪ Saving in infrastructure cost of the OHW itself ▪ 'Heritage Friendly' particularly in Hobart Waterfront, Mawson Place, if this is perceived as an issue ▪ Efficient regenerative braking saves energy	▪ Early stage of development of technology ▪ High capital cost as 'start up' technology ▪ Higher operating costs the some of the alternatives

Battery powered vehicles are worthy of consideration for HLR, provided the issues of cost, availability and functionality can be addressed.

Super Capacitors are also used to store energy for traction power. These can provide high discharge rates which can assist vehicle acceleration, but are not considered suitable for continuous applications in their current form of development.

Mechanical Energy Storage

The primary application of mechanical energy storage to traction power of road and rail vehicles is the use of high speed flywheels. These have been used in the past to power buses and more recently have been used on the proposed Parry People Movers. These vehicles seat 20 people, are available in high or low floor and require ‘charging’ every 800m, although ‘charge’ time is only 30 seconds. A small diesel motor helps with start up and emergency operation.

Whilst good advances have been made in flywheel materials and electromagnetic bearings it is not considered appropriate to consider such technology for HLR in its current state of development.

Diesel Power

Diesel powered railcars are widely used in Metro Rail and Heavy Rail passenger services all over the world. Heavier diesel passenger railcars are often called Diesel Multiple Units (DMUs) whilst lighter units have historically been referred to as ‘Rail Motors’, in recognition of their original development from motor bus technology, but this term has now fallen out of favour.

Photograph 11 – *Ottawa O-Train DLR Vehicle*

Diesel powered ‘metro’ systems were the mainstay of the metropolitan rail passenger service in Perth and Brisbane, prior to recent electrification. In Adelaide diesel power provided many years of service and is only now being converted over to electric traction. Even with Melbourne’s early adoption of electrified suburban rail, ‘rail motors’ serviced some of the outer areas such as Bacchus Marsh for many years.

Photograph 12 – *Stadler GTW 2/6 DLR Vehicle, Austin USA*

Light rail, however is different to metro, and a number of purpose designed Diesel Light Rail (DLR) vehicles are in use in various cities around the world.

Modern DLR now incorporate low floor, are far more efficient, quieter, accelerate faster and more smoothly and produce less emissions. Many of the modern vehicles are able to run on bio diesel fuel.

Excellent examples of DLR include Ottawa’s O-Train which commenced operation in 2001 uses Bombardier vehicles, and although there have been a few start up issues on this project they relate to the system itself rather than the vehicle technology.

Of particular interest is the Stadler GTW 2/6 vehicle. This consists of a small central power car and a trailer car at each end. The trailer cars are low floor, and access is available through the power car to each trailer. The power car can be either diesel or OHW electric. These vehicles, in diesel configuration, have run on the New Jersey River Line in the US since 2004. Similar vehicles run on the Austin Light Rail that opened in 2010. In Narrow Gauge form, Stadler GTW 2/6 vehicles in OHW form run on the Puy de Dome line in France.

Another DLR vehicle of interest is the Regio Citadis, more recently called the Citadis Dualis. These are diesel electric hybrid vehicles and are available in a number of variants including versions that are more towards Metro style than LRVs.

As mentioned above, the choice of a LRV for HLR must fulfil the requirements of a low cost entry whilst not causing obsolescence. DLR might be a good way to commence, knowing that they could be run in parallel with OHW powered vehicles in the future, or indeed used on new, more lightly populated routes, once the line to Claremont becomes established.

Alternatively, in the case of the Stadler GTW 2/6 vehicle, it would seem entirely possible to replace the diesel power car with an OHW powered electrical alternative. Whilst we have not discussed this with the manufacturer, as the diesel power car is in fact diesel/electric, it may just be a matter of retrofitting transformer/rectifiers to these power cars to convert them to OHW operation. Similar conversion may be possible for other DLR vehicles.

ADVANTAGES	DISADVANTAGES
▪ Lower initial capital cost of system due to no OHW ▪ No stray currents and easier rail communications	▪ Higher energy cost ▪ Reliance on fossil fuels, but note possibility of biodiesel ▪ Need for a fuelling facility and possible downtime for fuelling ▪ Higher maintenance costs

Mixing Heavy and Light Rail

One of the desirable attributes of HLR is that heavy rail or heritage vehicles should be able to use the line from time to time. This heavy rail use could take the form of locomotive-drawn freight trains and/or heritage vehicles of various types. It is expected that with the opening of the Brighton Transport Hub there will be very little rail freight demand on the line between Hobart and Brighton, however the possibility of occasional use still exists.

Hyder understands that there is a proposal for heritage vehicles to be using the line. With an introduction of an electronic interlocking signalling system this option would be made possible. There are few alternatives of operating arrangement and it is critical that these are agreed at an early stage of the development to enable implementation of any specific requirements. Some of the options that could be considered include: running a heritage service in lieu of a light rail service; running a heritage service in between light rail services when the frequency of light rail services would allow it (this would require coordination prior to implementation) and running the heritage or freight services outside the hours of the light rail service operation. If heavy rail vehicles are to operate during the operation of the light rail services, due to the higher consequence of a potential collision a ‘crash avoidance’ system, also known as Automatic Train Protection, would need to be introduced. The cost of such system would be adding approximately $5M to the project.

Until relatively recent times track sharing between light rail and heavy rail was seen as something to be avoided, one of the main reasons for this was safety, specifically the differing buffering strengths of heavy and light rail vehicles, something that increased with the advent of lighter, 100% low floor vehicles.

However the city of Karlsruhe, Germany has pioneered the use of track sharing, even to the extent of developing vehicles that can operate on either 750VDC or high voltage AC OHW.

Karlsruhe has done this by a combination of initiatives including ‘crashworthiness’, the ability of a vehicle to survive a crash, ‘crash avoidance’, the ability of the rail system to avoid the crash, and ‘crash attenuation’, the ability of a rail car to deform in such a way as to absorb energy. These and other factors are combined into what has become known as the ‘Karlsruhe Model’ for track sharing, and has been adopted in a number other cities, particularly in Germany.

Rolling Stock Recommendation

As can be seen above, there is a wide choice of LRV types and within them a range of vehicles and manufacturers.

Important considerations in final selection of the vehicle will be overall system cost and flexibility for future operations, but a prime requirement is simply to get a basic, safe, reliable system up and running to re-introduce Hobart commuters to urban rail travel.

For this reason we believe it would be unwise to make the success of a new system reliant on developing and emerging technologies, no matter how attractive they may appear. These technologies are best suited to adoption on existing and well-developed systems, where the development of the technology, particularly its timing, does not pose a threat to the introduction of the system itself.

Battery powered and super-capacitor powered vehicles have made enormous strides in their development over recent years and offer some real possibilities in particular applications, but currently their use as a sole power source has not yet been demonstrated on a day-to-day operating system.

In addition, the capital cost of battery vehicles is yet to be established, and as with much emergent technology, initial costs will be inevitably be high.

Therefore to move toward battery systems with a view to saving the initial capital cost of OHW, is highly likely to end up as counterproductive.

Diesel LRVs on the other hand is a well established technology that has in itself been through strong technological development to the extent that noisy, smelly and dirty diesel rail cars are a thing of the past.

The options recommended for rolling stock include the diesel vehicles and the use of electrical units with overhead traction power supply.

The selection of vehicles will be driven by what is available on the market at the time of purchase. This would also significantly impact on the cost of the vehicles. Overhead power system is the most common system and procurement of such vehicles that would be adequate for the HLR is more likely at relatively lower cost. However if adequate diesel units are available they would generally be at a lower cost of the electrical vehicles. In both cases, the cost of the units is quite uncertain and can vary significantly.

The actual vehicle should not be chosen yet, however, there is some sense in considering vehicles such as the Stadler GTW 2/6 that may be able to be converted from initial diesel operation to OHW operation in the future. The diesel units can also be replaced in the future with battery powered units when the technology is better developed.

Some mention has been made of the possibility of second hand vehicles. Whilst we have not done an extensive search for such vehicles initial indication is that these may be available from some parts of the world, but in Hobart the gauge will limit the availability. Savings may evaporate quickly if complete new 1067mm bogies are required to be fitted to 1000mm gauge vehicles. However, procurement of a second hand fleet should be given a serious consideration at the time of system implementation as this may provide a significant saving in the overall budget.

5.8 Signalling – Light Rail Signalling Systems

This section provides a general description of signalling requirements and the alternative system considered in the development of the OOSMs. The purpose of a signalling system is primarily to prevent:

- collision of rail vehicles
- controlled interaction with road vehicles and pedestrians

LRVs will not collide with each other if they are not permitted to occupy the same section of track at the same time, Therefore rail lines are divided into sections known as blocks. In normal circumstances, only one vehicle is permitted in each block at a time. This principle forms the basis of most rail safety systems. A signalling system provides a means to control the rail traffic, which essentially passes information to the driver relating to the state of the line ahead.

It is proposed that the HLR system will have light rail vehicles running in both directions (bidirectional), in 15 minute, or shorter intervals in the future, and therefore consideration will be given here to the most appropriate system that provide a high level of safety and is cost effective. A major consideration for any rail system is that a Safety Management System (SMS) needs to be established as part of the introduction of a Light Rail System.

Two systems were considered for development of the OOSMs. The selection was based on meeting the safety requirements and maintaining a low cost solution. The two systems considered were:

- Train Order System
- Electronic Interlocking Signalling System

The electronic interlocking signalling system as described in Section 4 was deemed as the optimal system. This system was assessed to provide better safety due to the lack of reliance on human control as is required with the train order system, which is generally becoming obsolete. The electronic interlocking signalling system does attract higher capital cost but the operational cost reduces and the potential introduction of heritage or freight use of the line with the light rail system will be made safer. This system would also provide benefits for future extension of the light rails system or with increasing the capacity by introduction of more frequent services.

Train Order System

The Train Order Radio system is a simple signalling system which operates on verbal instruction. The system is used to prevent rail traffic entering an occupied section. Authority to enter a section is only given by a valid order. The authority would be given by a controller (dispatcher) with appropriate information being exchanged to ensure that there is no confusion that could potentially lead to a LRV entering an occupied section and potentially colliding with an oncoming vehicle.

The basic authority for movements is the timetable graph. It is used as the first level of regulation for all LRVs. The timing and priority for units is laid down in the timetable, i.e. the timetable dictates the departure times and then, if times cannot be adhered to, which unit should move first and which should wait for others.

A Timetable Graph depicts the timetabled progress of rail vehicles, with stations listed down the vertical axis (based on their respective spacing apart) and time on the horizontal axis. Each rising and falling line on the graph represents a single LRV.

To enable a LRV to proceed into a section, the driver will request entry (authority) into a section from the controller/dispatcher, to which the controller would respond with appropriate authorisation. The controller is responsible for the traffic movement into sections.

ADVANTAGES	DISADVANTAGES
▪ No special infrastructure required (apart from on board radio system and control centre) ▪ Reduced cost	▪ Reliant on verbal communication between drivers and controller ▪ Reliant on correct interpretation of authorities ▪ Reliant on operation of radio system ▪ Possible delay while driver receives authority to proceed ▪ Dependent on having a full time Controller ▪ No signals to provide driver with any visual indications

6 RAIL TRANSPORT MODELLING

Rail modelling with a sample of iterations was undertaken as part of the analysis to assist with the assessment of passing loop requirements, the number of vehicles that would be required and to provide an option of a travel timetable in accordance with the parameters agreed for the project. It should be noted that the rail modelling only provides examples of how the system could operate and the number of loops and units that would be required for the parameters agreed. The modelling does not set the location of loops and stops but only considers a possible option for consideration of costs.

Prior to implementation of a light rail system, detailed analysis would be undertaken that would consider specific requirements including future proofing of the system.

Future Increases in Demand

In consideration of future increases in demand, increases of frequency of the service or extension of the line further north from Claremont, there are various options that could be considered which will depend on the specific requirements. These would include options such as:

- extension of the existing loops to accommodate longer vehicles with larger capacity
- increase in the number of vehicles used on the system
- increase in the number of loops
- development of new timetables in accordance with the number of loops and vehicles used

This section provides general information on rail modelling and sample of iterations of a rail transport model developed for this project.

Rail Modelling

A rail transport model provides a means of methodically forecasting outcomes based on a number of fixed and variable parameters. The software tool, OpenTrack, can be used to build a virtual model of the infrastructure of a given section of track. Based on a given set of assumptions and parameters, the model can be used to derive a number of measured outputs. For this purpose, OpenTrack was used to simulate the time vehicles take to run between the proposed passenger stops given various scenarios. This data was then used in the Viriato timetabling software package for production of respective timetable data and graphs. The advantages of using such a simulation tool for testing the scenarios are:

- multi unit simulation – run as many or as few vehicles for the purpose of testing scenarios
- variable analysis – can be used to test the impact of changing any parameters and the resulting benefits to the rail service
- demonstrates time benefits of any infrastructure upgrades

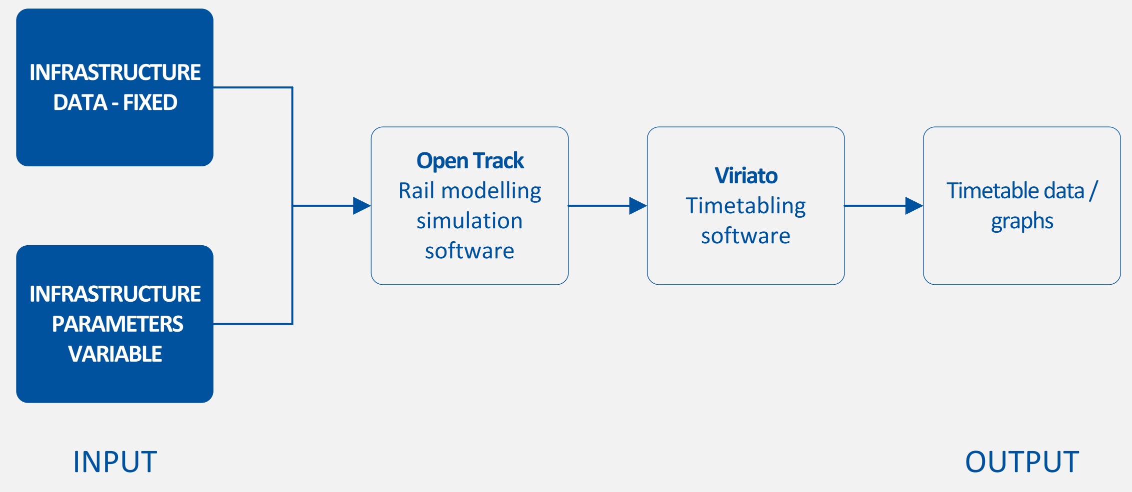

Figure 12: *Software modeling tool*

In configuring the simulation tool for the HLR system, a number of key input parameters comprising existing infrastructure information were entered.

Key input parameters included:

- headway of the vehicles - aim to achieve 15 minutes spacing between vehicles in both directions
- length of the railway line
- curve radius – based on data as supplied by TasRail
- gradient – based on data as supplied by TasRail
- position/distance between each passenger stop
- number of passenger loops

The following parameters were varied for the purpose of optimising the timetable based on various scenarios:

- line speeds (sectional run times, i.e. run times between stops).
- stops dwell times - dwell (stop) time was based on passenger loading times for the two types of LRVs considered, diesel and electric vehicles, due to loading limitations. Therefore an average of 20 seconds dwell time at each intermediate station was allowed for electric LRVs and 30 seconds allowed for diesel LRVs.

The following input parameters were varied:

- amount of rolling stock (number of LRVs)
- number of passing loops
- position of passing loops

6.1 Scenarios

The details of the rail simulation for the HLR system are provided in *Appendix B*. The following provides a summary.

The rail modelling considered the following four scenarios

Table 3: Rail Modelling Scenario

SCENARIO	MAX LINE SPEED	DWELL TIMES
01	45 kph	30 secs (DLRV)
02	45 kph	20 secs (ELRV)
03	60 kph	30 secs (DLRV)
04	60 kph	20 secs (ELRV)

** (ELRV – Electric Light Rail Vehicle, DLRV – Diesel Light Rail Vehicle)

These scenarios assumed that there are no delays at level crossings, as the LRV has priority. In addition, speed limits are placed on the track curves that are contained within the alignment. The speed limits vary depending on the curve radius.

For example, the speed limit on a track curve radius of 100m would be limited to 30kph.

The outputs of the simulations for each of the scenarios are shown in the graphs contained in the rail simulation attachment. The graphs depict the relationship between:

- Time vs. Distance travelled
- Speed vs. Distance travelled – with a constraint being placed on the maximum allowable speed

Based on the simulation data and using the DLRV run times, the next step was to determine the optimal crossing site locations on the single track using the timetable generation software. A total of five iterations were generated as summarised below.

1	Line speed max. 45kph with limits on existing curves, 3 crossing loops, 6 LRVs *Result – All crossing locations situated between stops*
2	Line speed max. 45kph with limits on existing curves, 4 crossing loops, 5 LRVs *Result – 2 crossing locations at stops, 2 situated between stops*
3	Line speed max. 45kph with limits on existing curves, 5 crossing loops, 5 LRVs *Result – Additional intermediate crossing points are required*
4	Line speed max. 60kph with limits on existing curves, 3 loops, 5 LRVs *Result – co-located passing loops at stops and passing line at Hobart*
5	Line speed 60kph plus with limits on existing curves, 3 loops, 4 LRVs *Result – 2 crossing locations at stops, 1 situated between stops*

Ideally the positions of the passing loops would be located at the passenger stations so that LRVs have ability to pick up passengers while waiting for an oncoming LRV to cross.

6.2 Summary

With a speed limit of 45kph in order to achieve departures from both termini at the same time after each hour three passing loops and six vehicles are required. If departures from the outer termini are after a minimum turnaround time then four passing loops and five vehicles are required. The travel time between Hobart and Claremont varies between 29 and 27 minutes dependent on the type of vehicle used. This does not include turnaround time which adds approximately three minutes at each terminus.

With a speed limit of 60kph it is assessed that three passing loops and five vehicles are required. The travel time between Hobart and Claremont varies between 23 and 21 minutes dependent on the type of vehicle used. This allows for a turnaround time of 30 minutes or less for section turnaround time bringing efficiencies in the service.

It is assessed that with a travel time of 22 minutes or less, which can be achieved with a speed limit of just over 60kph, the model would require three passing loops and four vehicles. It is proposed that this is used as an option in the cost benefit analysis and the major upgrade of the track would accommodate a speed limit of approximately 65kph.

It is recommended that in addition to the number of units assessed as required for operating a 15 minute interval service, an additional unit is considered to be procured as a reserve. This unit can be used when maintenance of vehicles is undertaken or failure of a unit occurs. The reserve unit could also provide additional capacity should an increased level of patronage be experienced.

A full report on the rail modelling undertaken is enclosed in *Appendix B*.

7 CONCLUSION

The Hobart Light Rail (HLR) Business case study undertaken on behalf of the DIER has considered a number of options for the development of the Optimal Operating Service Models (OOSMs). The parameters used for the purpose of the study have been agreed through the consultation process or have been instructed by DIER.

As a result of the consultation process and analysis during the project, two OOSMs have been recommended as outlined in Section 4 of this report.

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

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

- the existing track, although currently is used for freight, is deemed unsuitable for use as passenger rail in its current condition.
- the terminus in Hobart at this stage it is recommended to be the Waterfront, Mawson Place or extended to Elizabeth Street south of Davey Street via Morrison Street.
- the most direct route should be adopted through the rail yards, with the possibility of amending the route in the future to accommodate the long term plan of the area.
- the preferred configuration is a single line with passing loops.
- electronic interlocking signalling system is recommended to be introduced.
- OHW electrification or use of diesel powered units are the two recommended options to be considered. The selection would be based on the attractiveness of the system and the cost associated with the alternatives. The OHW system provides a green energy solution whereas the diesel powered units could potentially provide a lower capital cost alternative if units are available at the time of purchase.
- vehicles should preferably be substantially low floor.

Cost estimates have been developed for the OOSMs and the alternative options that have been considered in this report. The information from this report will be used for cost benefit analysis by ACIL Tasman as Stage 3 of this project.

APPENDIX A – Cost Estimate Report

01 June 2011

Northern Suburbs Light Rail

Estimate for Optimal Operating Service Models

Introduction

Aquenta Consulting has been engaged by Hyder Consulting to provide budget estimates for the Light Rail Business case. The estimates which Aquenta has been asked to consider consist of two Optimal Operating Service Models being listed below.

The cost estimates are indicative and are based on limited information available. They are for use in a cost benefit analysis for implementation of light rail into Hobart. Two OOSMs and a number of alternative options have been costed. The two OOSMs are

- Introduction of a light rail system between Hobart and Claremont with a use of diesel powered units
- Introduction of a light rail system as above and using overhead traction power instead of diesel powered units.

Aquenta has also been asked to provide some additional estimates for the following items:

1. Cost of partial upgrade of the track as an alternative to the major upgrade used in the OOSMs
2. Extension of the service from Hobart Waterfront, Mawson Place through Morrison Street onto Elizabeth Street south of Davey Street
3. Use of a train order system

Other high level costs considered:

Additional costs for a second track along the current path alignment

1. Extension of the service from Hobart Waterfront, Mawson Place to Elizabeth Street
2. Alternative alignment of the route running on the north side of Davey Street
3. Alternative alignment of the route running through the rail yard

Optimal Operating Service Model OOSM 01 (Diesel Units)

The OOSM 01 estimate is based on use of diesel units for operations of the railway line. The estimate for this OOSM is $79,571,000 (refer OOSM 01 estimate spreadsheet). The estimate assumes the following:

- Major track upgrade would of removal of the rail sleepers and ballast over the entire length of the alignment, the area is stripped, the subgrade is improved, a capping layer is then placed over the subgrade and the track is then reconstructed
- It has been assumed that approximately 20% of the track, sleepers and ballast can be reused
- It has been assumed that a majority of the existing or purchased second hand track and sleepers are used in the balance of the installation
- It has been assumed that a majority of the alignment will require ballast replacement and that a proportion of the ballast will be able to be re used by cleaning and then resurfacing areas where there is a sufficient amount of base ballast
- A new maintenance facility will be constructed along the alignment with one entry road and a pit inside the building for maintenance of rolling stock
- Level crossings require to be upgraded to accommodate passenger light rail movements by installation of new signalling infrastructure

- Signalling would consist of an electronic interlocking system type installation
- Park and ride facilities for approximately 300 vehicles at Claremont and Bus interchange facilities for three bus stops at Claremont and Glenorchy
- Three passing loops to allow for safe passing of light rail vehicles
- Four Light rail vehicles would be required plus a reserve vehicle
- Six stops to be constructed along the route with and a major terminus at Hobart Waterfront Mawson Place

Optimal Operating Service Model OOSM 02 (OHW Traction Power)

The OOSM 02 estimate is based on use of overhead traction power and electrical units. The estimate for this OOSM is $92,227,000 (refer OOSM 02 estimate spreadsheet). The estimate assumes that following:

- The installation of overhead traction power would be for the full length of the route as well as installation of overhead catenary in the maintenance depot.
- All other elements are the same as OOSM 01

Costs for land acquisition have not been included if required for construction of a new maintenance facility.

Variations to the OOSM

Aquenta has also provided some additional costs (refer 'Additional costs related to both OOSMs' spreadsheet) relating to the both OOSMs which consist of the following:

1. Partial update of the track – approximately one third of the alignment would require ballast / sleeper / rail replacement without any subgrade or capping improvements and approximately one third of the track would only require minor sleeper and ballast replacement and some rail grinding
2. Additional cost of extending the service to Elizabeth Street South of Davey Street via Morrison Street.
3. Provision of a train order system, reduction in cost

Risk Modelling

The risk modelling has been conducted on information provided to Aquenta for contingent risk. The inherent risk items have been extracted from the estimates using parameters of -10% to +30%. Both the inherent risk and contingent risk have been run simultaneously to provide a total risk adjusted project cost. The figure chosen for the risk adjusted project cost is based on a P50 amount.

311075 Northern Suburbs Light Rail

Diesel Units Rolling Stock - OOSM 01

aQuenta consulting

Hobart Waterfront, Mawson Place to Claremont					
	Qty	Unit	Rate	Subtotal	Total
Track					33,544,000
Clearing / Stripping	52,920	m²	5	264,600	
Remove existing rail and sleepers and stockpile	14,700	m	85	1,249,500	
Subgrade improvement - replace unsuitable with imported, disposal of excavated material and geotextile to base	52,920	m²	95	5,027,400	
Capping Layer	52,920	m²	20	1,058,400	
Drainage	1,000	m	350	350,000	
Re establish swale drains	13,970	m	60	838,200	
Subsoil drains along alignment	13,970	m	60	838,200	
Subgrade preparation	52,920	m²	5	264,600	
Supply and install passing loop turnouts	8	no	250,000	2,000,000	
Lay new track including Sleepers / ballast / tamping	4,300	m	900	3,870,000	
Lay existing sleepers	4,300	m	78	335,400	
Lay new sleepers	7,460	m	275	2,051,500	
Lay existing or supplied rail	11,760	m	230	2,704,800	
Rail grinding	11,760	m	60	705,600	
Ballast replacement	8,820	m	150	1,323,000	
Re use existing ballast - clean and resurface	5,880	m	260	1,528,800	
Track tamping	11,760	m	25	294,000	
Signalling - Electronic Interlocking System	1	Item	5,000,000	5,000,000	
Level crossing upgrades	18	ea	190,000	3,420,000	
Intersection modification (Evans Street)	1	ea	250,000	250,000	
Service proofing	1	ea	170,000	170,000	
Structure					3,200,000
Track reconstruction on bridge over creek at Glenorchy	1	Item	100,000	100,000	
Light rail depot including 1 x 100m stabling roads	1	Item	3,100,000	3,100,000	
Stops					3,989,700
Includes Hobart Waterfront - Mawson Place, New Town, Moonah, Derwent Park, Glenorchy, Berriedale, Claremont					
Stops	6	ea	150,000	900,000	
Hobart Waterfront, Mawson Place terminus	1	ea	400,000	400,000	
Pathways / ramps	210	m	320	67,200	
Pedestrian crossings	7	ea	10,000	70,000	
Power to stops	7	Item	100,000	700,000	
Bus interchange and park & ride facilities	1	Item	1,800,000	1,800,000	
Drainage	150	m	350	52,500	
Urban design / landscaping / bush care	**0.5%**	**Item**	**40,733,700**	**203,669**	**$ 203,669**
Total Contractor's Costs					**$ 40,937,369**
Client Costs					
Project management & project controls			5.00%		$ 2,046,900
Design			4.50%		$ 1,842,200
Other Costs					
Rolling stock - Diesel Units	5	ea	5,000,000		$ 25,000,000
Subtotal					**$ 69,826,469**
Contingency					$ 7,245,293
Rolling Stock Contingency					$ 2,500,000
Total CAPEX Cost					**$ 79,571,762**

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OHW and Electrical Units Rolling Stock - OOSM 02

aQuenta consulting

Hobart Waterfront, Mawson Place to Claremont					
	Qty	**Unit**	**Rate**	**Subtotal**	**Total**
Track					45,044,000
Clearing / Stripping	52,920	m²	5	264,600	
Remove existing rail and sleepers and stockpile	14,700	m	85	1,249,500	
Subgrade improvement - replace unsuitable with imported, disposal of excavated material and geotextile to base	52,920	m²	95	5,027,400	
Capping Layer	52,920	m²	20	1,058,400	
Drainage	1,000	m	350	350,000	
Re establish swale drains	13,970	m	60	838,200	
Subsoil drains along alignment	13,970	m	60	838,200	
Subgrade preparation	52,920	m²	5	264,600	
Supply and install passing loop turnouts	8	no	250,000	2,000,000	
Lay new track including Sleepers / ballast / tamping	4,300	m	900	3,870,000	
Lay existing sleepers	4,300	m	78	335,400	
Lay new sleepers	7,460	m	275	2,051,500	
Lay existing or supplied rail	11,760	m	230	2,704,800	
Rail grinding	11,760	m	60	705,600	
Ballast replacement	8,820	m	150	1,323,000	
Re use existing ballast - clean and resurface	5,880	m	260	1,528,800	
Track tamping	11,760	m	25	294,000	
OHW Traction System - Electrification of the line	1	Item	11,500,000	11,500,000	
Signalling - Electronic Interlocking System	1	Item	5,000,000	5,000,000	
Level crossing upgrades	18	ea	190,000	3,420,000	
Intersection modification (Evans Street)	1	ea	250,000	250,000	
Service proofing	1	ea	170,000	170,000	
Structure					3,200,000
Track reconstruction on bridge over creek at Glenorchy	1	Item	100,000	100,000	
Light rail depot including 1 x 100m stabling roads	1	Item	3,100,000	3,100,000	
Stops					3,989,700
Includes Hobart Waterfront - Mawson Place, New Town, Moonah, Derwent Park, Glenorchy, Berriedale, Claremont					
Stops	6	ea	150,000	900,000	
Hobart Waterfront, Mawson Place terminus	1	ea	400,000	400,000	
Pathways / ramps	210	m	320	67,200	
Pedestrian crossings	7	ea	10,000	70,000	
Power to stops	7	Item	100,000	700,000	
Bus interchange and park & ride facilities	1	Item	1,800,000	1,800,000	
Drainage	150	m	350	52,500	
Urban design / landscaping / bush care	**0.5%**	**Item**	**52,233,700**	**261,169**	**$ 261,169**
Total Contractor's Costs					**$ 52,494,869**
Client Costs					
Project management & project controls			5.00%		$ 2,624,800
Design			4.50%		$ 2,362,300
Other Costs					
Rolling stock - electrically powered units	5	ea	5,000,000		$ 25,000,000
Subtotal					**$ 82,481,969**
Contingency					$ 7,245,293
Rolling Stock Contingency					$ 2,500,000
Total CAPEX Cost					**$ 92,227,262**

Alternatives for Consideration

1	**Partial Track Upgrade for 45kmh speed limit**			
	Additional Cost			
	Reduction of $13m	-	13,000,000	
	Additional unit		5,000,000	
	Increase in maintenance cost per year		2,200,000	per year
	Total for additional cost	**-**	**5,800,000**	
2	**Extension to Elizabeth Street South**			
	Additional Cost			
	Civil track and overhead works		2,500,000	Potentially additional unit would be required adding $5m to the cost
	Total for additional cost		**2,500,000**	
3	**Use of Train Order System**			
	Additional Cost			
	Reduction in capital cost for signalling	-	3,500,000	
	Operating cost per year		375,000	per year
	Total for additional cost	**-**	**3,125,000**	

Other Costs

1	**Davey Street (North Side)**		Alternative route alignment
	service relocations	1,000,000	
	civil works	2,000,000	
	track construction	450,000	
	traffic reconfiguration	500,000	
	reconfigure intersections	800,000	
	Total Davey street North side	**4,750,000**	
2	**Route through existing docks area**		Alternative route alignment along Evans and Hunter St
	Track construction	1,800,000	
	demolition	50,000	
	civil works	500,000	
	services	400,000	
	intersection reconfiguring	500,000	
	Total for route through docks area	**3,250,000**	

Maintenance and Operating Costs

1	**Maintenance Costs**		
	OOSM 01 and 02	163,000	Cost per year for first 5 years then same as the alternative ($2,400,000)
	OOSM 02 additional for OHW	150,000	per year for the first 5 years
	Partial Upgrade Alternative	2,400,000	per year
2	**Operating Costs**		
	OOSM 01 per year	2,750,000	per year
	OOSM 02 per year	2,500,000	per year

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Partial Track Upgrade

Hobart Waterfront, Mawson Place to Claremont	Qty	Unit	Rate	Subtotal	Total
Track					20,394,200
Clearing / Stripping	17,464	m²	5	87,318	
Remove existing rail and sleepers and stockpile	4,851	m	85	412,335	
Subgrade improvement - replace unsuitable with imported, disposal of excavated material and geotextile to base	17,464	m²	95	1,659,042	
Capping Layer	17,464	m²	20	349,272	
Drainage	330	m	350	115,500	
Re establish swale drains	4,610	m	60	276,606	
Subsoil drains along alignment	4,610	m	60	276,606	
Subgrade preparation	17,464	m²	5	87,318	
Supply and install passing loop turnouts	10	no	250,000	2,500,000	
Lay new track including Sleepers / ballast / tamping	2,530	m	900	2,277,180	
Lay existing sleepers	2,321	m	78	181,022	
Lay new sleepers	1,560	m	275	429,000	
Lay existing or supplied rail	2,321	m	230	533,784	
Rail grinding	4,851	m	60	291,060	
Ballast replacement	1,601	m	150	240,125	
Re use existing ballast - clean and resurface	3,250	m	260	845,044	
Minor sleeper replacement	2,072	m	275	569,869	
Track tamping	6,923	m	25	173,081	
Signalling	1	Item	5,000,000	5,000,000	
Level crossing upgrades	18	ea	190,000	3,420,000	
Intersection modifications (Evans and Hunter)	2	ea	250,000	500,000	
Service proofing	1	ea	170,000	170,000	
Structure					3,200,000
Track reconstruction on bridge over creek at Glenorchy	1	Item	100,000	100,000	
Light rail depot including 1 x 100m stabling roads	1	Item	3,100,000	3,100,000	
Stops					4,139,700
Includes Hobart Waterfront - Mawson Place, New Town, Moonah, Derwent Park, Glenorchy, Berriedale, Claremont					
Stops	7	ea	150,000	1,050,000	
Hobart Waterfront, Mawson Place terminus	1	ea	400,000	400,000	
Pathways / ramps	210	m	320	67,200	
Pedestrian crossings	7	ea	10,000	70,000	
Power to stops	7	Item	100,000	700,000	
Bus interchange and park & ride facilities	1	Item	1,800,000	1,800,000	
Drainage	150	m	350	52,500	
Urban design / landscaping / bush care	**0.5%**	**Item**	**27,733,900**	**138,670**	**$ 138,670**
Total Contractor's Costs					**$ 27,872,570**
Client Costs					
Project management & project controls			5.00%		$ 1,393,700
Design			4.50%		$ 1,254,300
Other Costs					
Rolling stock (does not include a reserve vehicle)	6	ea	5,000,000		$ 30,000,000
Subtotal					**$ 60,520,570**
Risk					$ 7,999,458
Total CAPEX Cost					**$ 68,520,028**

311075 Northern Suburbs Light Rail

New additional single track without OHW

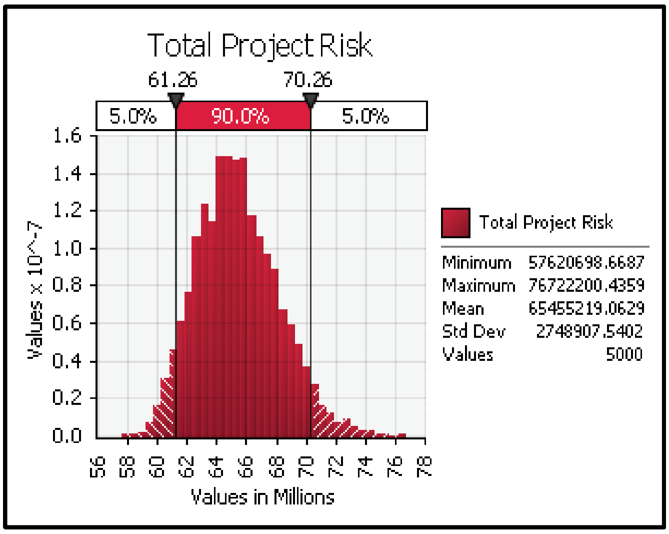
aQuenta consulting

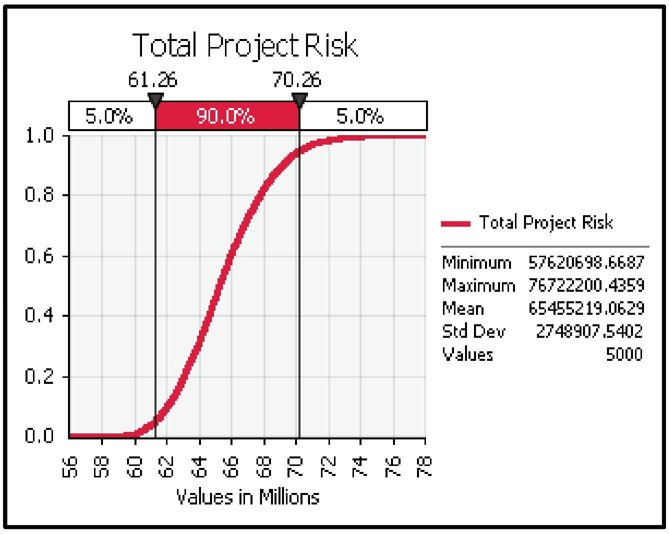
Hobart Waterfront, Mawson Place to Claremont					
	Qty	**Unit**	**Rate**	**Subtotal**	**Total**
Track					37,753,800
Clearing / Stripping (mainly at level crossings)	58,800	m^2	5	294,000	
Remove existing footpath & reconstruct new	14,700	m	700	10,290,000	
Subgrade improvement - replace unsuitable with imported, disposal of excavated material and geotextile to base	52,920	m^2	95	5,027,400	
Capping Layer	52,920	m^2	20	1,058,400	
Drainage	1,000	m	450	450,000	
New swale drains	14,700	m	40	588,000	
Subsoil drains along alignment	14,700	m	60	882,000	
Subgrade preparation	58,800	m^2	5	294,000	
Supply & install crossovers	5	no	500,000	2,500,000	
Supply and install turnouts	2	no	250,000	500,000	
Lay new track including Sleepers / ballast / tamping	16,300	m	900	14,670,000	
Signalling (reduction)	1	Item	- 1,500,000	- 1,500,000	
Level crossing upgrades (additional)	19	ea	100,000	1,900,000	
Within Hobart a single line is assumed due to space restricti	2	ea	350,000	700,000	
Service proofing (additional)	1	ea	100,000	100,000	
Structure					2,850,000
New bridge over creek at Glenorchy	1	Item	500,000	500,000	
Pedestrian subways (shared path through overbridges)	5	ea	420,000	2,100,000	
Urban design and landscape for additional track	1	Item	250,000	250,000	
Total Contractor's Costs					**$ 40,603,800**
Client Costs					
Project management & project controls			5.00%		$ 2,030,200
Design			4.50%		$ 1,827,200
Subtotal					**$ 44,461,200**
Contingency			25.00%		$ 11,115,300
Total CAPEX Cost					**$ 55,576,500**

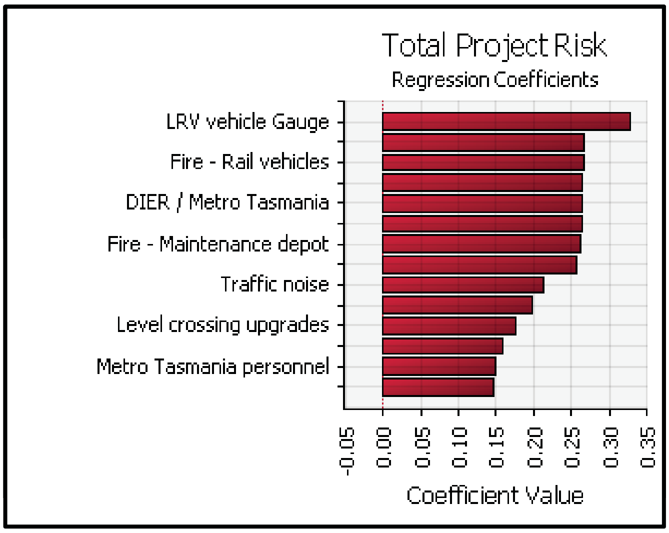
@RISK Output Report for Northern Suburbs Light Rail - Major Upgrade

Performed By: arthur.lambrianidis

Date: Thursday, 19 May 2011 4:12:28 PM







Simulation Summary Information

Workbook Name	Major
Number of Simulations	1
Number of Iterations	5000
Number of Inputs	180
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	5/19/11 17:10:52
Simulation Duration	00:01:19
Random # Generator	Mersenne Twister
Random Seed	979098087

Summary Statistics for Total Project Risk

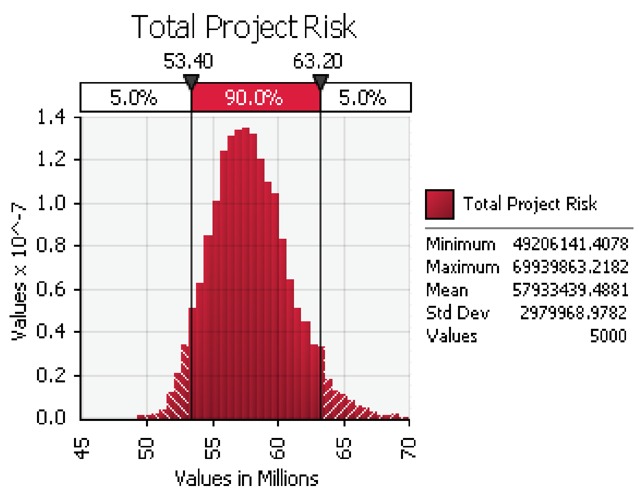
Statistics		**Percentile**	
Minimum	57620698.7	**5%**	61261165.3
Maximum	76722200.4	**10%**	62030878.8
Mean	65455219.1	**15%**	62621612.9
Std Dev	2748907.54	**20%**	63059010.4
Variance	7.5565E+12	**25%**	63457668.2
Skewness	0.39045347	**30%**	63897355.8
Kurtosis	3.06367	**35%**	64245939.6
Median	65243556.9	**40%**	64587958.5
Mode	66049885.4	**45%**	64914082.6
Left X	61261165.3	**50%**	65243556.9
Left P	5%	**55%**	65595162.3
Right X	70255020.8	**60%**	65954400.6
Right P	95%	**65%**	66351159.2
Diff X	8993855.41	**70%**	66790323.2
Diff P	90%	**75%**	67246310.8
#Errors	0	**80%**	67781227.6
Filter Min	Off	**85%**	68351508
Filter Max	Off	**90%**	69146095.1
#Filtered	0	**95%**	70255020.8

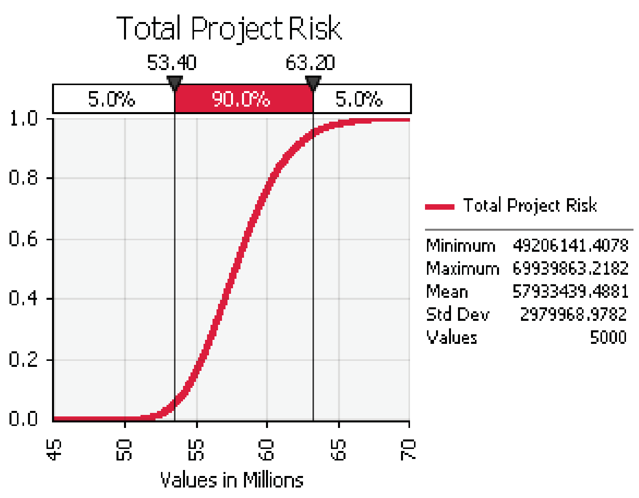
Regression and Rank Information for Tota

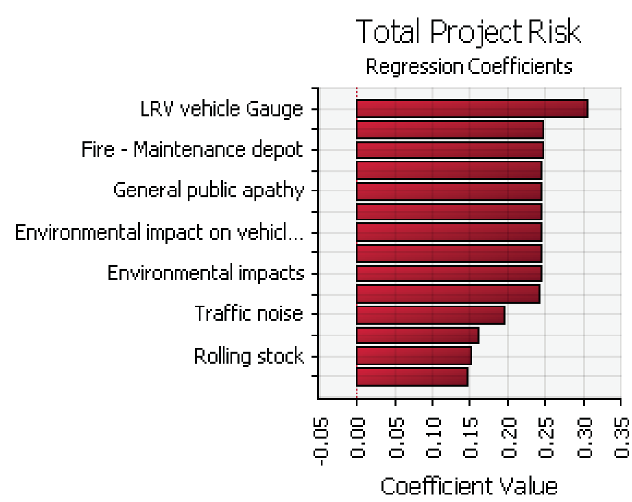
Rank	**Name**	**Regr**	**Corr**
1	LRV vehicle G	0.328	0.309
2	Environmenta	0.266	0.260
3	Fire - Rail veh	0.266	0.263
4	General public	0.265	0.254
5	DIER / Metro	0.264	0.246
6	Public Transp	0.263	0.248
7	Fire - Mainten	0.262	0.260
8	Subgrade imp	0.257	0.213
9	Traffic noise	0.213	0.195
10	Lay new track	0.197	0.167
11	Level crossing	0.177	0.157
12	Light rail depo	0.159	0.143
13	Metro Tasmar	0.148	0.137
14	Residents' Gr	0.146	0.136

@RISK Output Report for North Hobart Light Rail - Partial Track Upgrade

Performed By: arthur.lambrianidis
Date: Thursday, 19 May 2011 3:56:06 PM







Simulation Summary Information

Workbook Name	Partial
Number of Simulations	1
Number of Iterations	5000
Number of Inputs	195
Number of Outputs	1
Sampling Type	Latin Hypercube
Simulation Start Time	5/19/11 16:53:30
Simulation Duration	00:01:24
Random # Generator	Mersenne Twister
Random Seed	2115771853

Summary Statistics for Total Project Risk

Statistics		**Percentile**	
Minimum	49206141.4	**5%**	53398959.4
Maximum	69939863.2	**10%**	54301826.7
Mean	57933439.5	**15%**	54875934.6
Std Dev	2979968.98	**20%**	55389406.9
Variance	8.8802E+12	**25%**	55814947.9
Skewness	0.41611561	**30%**	56213775.2
Kurtosis	3.18949865	**35%**	56607090.8
Median	57730922.6	**40%**	56982060.7
Mode	58133941	**45%**	57347472
Left X	53398959.4	**50%**	57730922.6
Left P	5%	**55%**	58104809.4
Right X	63200589.6	**60%**	58477855
Right P	95%	**65%**	58878491.7
Diff X	9801630.16	**70%**	59324319.1
Diff P	90%	**75%**	59813235.1
#Errors	0	**80%**	60324052.4
Filter Min	Off	**85%**	61002046.4
Filter Max	Off	**90%**	61912133.7
#Filtered	0	**95%**	63200589.6

Regression and Rank Information for Tota

Rank	**Name**	**Regr**	**Corr**
1	LRV vehicle G	0.306	0.315
2	Public Transp	0.248	0.236
3	Fire - Mainten	0.247	0.257
4	Fire - Rail veh	0.246	0.227
5	General publi	0.245	0.253
6	Vehicle propu	0.245	0.258
7	Environmenta	0.244	0.249
8	DIER / Metro	0.244	0.236
9	Environmenta	0.243	0.261
10	On roads runr	0.242	0.224
11	Traffic noise	0.196	0.178
12	Level crossing	0.161	0.127
13	Rolling stock	0.151	0.158
14	Light rail depo	0.146	0.113

Indicative Rolling Stock Cost

Vehicle Type	Typical Model	Manufacturer	Where Operating	Approximate Range of Cost	Comments
Diesel Light Rail	Stadler GTW 2/6	Stadler	Austin Texas, USA	$4.5m - 6.5m	Bombardier O - Train vehicle is similar
Battery Power Light Rail	SWIMO	Kawasaki Heavy Industries	Demonstration line –Sapporo, Hokkaido, Japan	approximately $5m+	Currently not in commercial operation
OHW Powered Light Rail	Citadis 302	Alstom	Melbourne and Adelaide	$4.5m - $6.0m	Bombardier Flexity is similar Being proposed for use in the Gold Coast Light Rail system
Hybrid OHW/ Battery	Ameritram	Kinkisharyo	Demonstration line – Charotte NC, USA	approximately $5m+	Vehicles which are currently operating in Nice, France are similar but with lower travel range between recharging
Track Powered Light Rail	Citadis APS	Alstom	Bordeaux, France	$5m+	Bombardier Primove is similar

Maintenance costs for rail assets (new installation)

(Every FiveYears)					
	Qty	**Unit**	**Rate**	**Subtotal**	**Total**
Track					-
Ballast cleaning (full)	-	m	400	-	
Track tamping	-	m	7	-	
Ballast re-surfacing	-	t	160	-	
Rail grinding	-	m	37	-	
Re-sleepering (5% per annum)	-	ea	230	-	
Generally					649,750
Allow for bridge inspection works (every five years)	5	No	10,000	50,000	
Anti-graffiti paint treatment to bridges etc.	2,800	m2	25	70,000	
Graffiti removal	2,800	m2	10	28,000	
Weeding and general cleanup of track length (14,300 metres) (three out of five years)	36	Months	5,000	180,000	
Repairs/replacement to trackside fencing (say 5% per annum)	3,575	m	90	321,750	
Subtotal					**$ 649,750**
Contingency			20.00%		130,000
Subtotal					**$ 779,750**
Rail Corporation's Overheads			5.00%		39,000
Total OPEX Cost	**5**	**years**			**$ 818,750**
	1	year			163,750

Maintenance costs for rail assets (not new installation)

(Every FiveYears)					
	Qty	**Unit**	**Rate**	**Subtotal**	**Total**
Track					8,668,400
Ballast cleaning (full)	15,500	m	400	6,200,000	
Track tamping	15,500	m	7	105,400	
Ballast re-surfacing	6,045	t	160	967,200	
Rail grinding	15,500	m	37	573,500	
Re-sleepering (5% per annum)	3,575	ea	230	822,250	
Generally					649,750
Allow for bridge inspection works (every five years)	5	No	10,000	50,000	
Anti-graffiti paint treatment to bridges etc.	2,800	m2	25	70,000	
Graffiti removal	2,800	m2	10	28,000	
Weeding and general cleanup of track length (14,300 metres) (three out of five years)	36	Months	5,000	180,000	
Repairs/replacement to trackside fencing (say 5% per annum)	3,575	m	90	321,750	
Subtotal					**$ 9,318,150**
Contingency			20.00%		1,863,700
Subtotal					**$ 11,181,850**
Rail Corporation's Overheads			5.00%		559,100
Total OPEX Cost	**5**	**years**			**$ 11,740,950**
	1	year			2,348,190

Operational costs for Hobart Light Rail per annum

Costs per annum					
	Qty	**Unit**	**Rate**	**Subtotal**	**Total**
Rail operations					2,750,000
Drivers	12	no	85,000	1,020,000	
Staff	3	no	85,000	255,000	
Fuel	250,000	litre	1.50	375,000	
Rolling Stock maintenance	1	Item	600,000	600,000	
Other	1	Item	500,000	500,000	
				-	
Subtotal					**$ 2,750,000** -
Total cost per annum	**1**	**year**			**$ 2,750,000**

OOSM 01	**$ 2,750,000**
OOSM 02	**$ 2,500,000**

APPENDIX B – Rail Modelling Report

Hobart Light Rail Study

for

Hyder

Version	Date	History
1	3 May 2011	Initial Issue

Unit 6, 3 Sutherland Street
Clyde NSW 2142
Phone + 61 2 9637 5830
Fax + 61 2 9637 6350
www.plateway.com.au

Hobart Light Rail Proposal

Plateway Pty Ltd used the OpenTrack rail modelling software to create a model of the proposed Hobart to Claremont light rail line. The model was created from curve and gradient data along with additional information provided by Hyder. In addition to the alignment that would be resumed from the Hobart to Claremont heavy railway right of way; the model also extended some 300 metres from the current Hobart terminus into the city of Hobart to arrive at Mawson Place (the intersection of Davey and Argyle Streets.) The OpenTrack assumptions and outcomes are shown in the tables below.

The OpenTrack data was then interpreted and developed as the basis for a regular interval timetable service using the SMA+ Viriato timetable software. The regular interval headway deemed appropriate by Hyder was 15 minutes. A number of iterations were used to service a suitable timetable. From this it was possible to indicate possible infrastructure needs and the amount of rolling stock required to operate a basic service. No assumption was made about demand.

Assumptions

The line is a single, non-electrified, heavy railway (currently used for freight only services). Engineering reports suggest the line is available to run equipment at a maximum speed of between 35 kph (on street running) and 45 kph (on own right of way) at current maintenance levels. Historical evidence suggests this could be upgraded to 60 kph with a suitable maintenance regime.

Equipment for use on these services is considered to be derived from existing proven and available technology, capable of operating in coupled multiple units (if required) and driven from either end of the vehicle. It was assumed that this equipment can operate on the existing rail profile.

It was assumed that, although the line is non-electrified, it could be electrified.

Four OpenTrack scenarios were used to create the basis for a timetable:

Scenario	Equipment	Track max line speed	Dwell times
1	DLRV	45 kph	30 sec
2	ELRV	45 kph	20 sec
3	DLRV	60 kph	30 sec
4	ELRV	60 kph	20 sec

Unit 6, 3 Sutherland Street
Clyde NSW 2142
Phone + 61 2 9637 5830
Fax + 61 2 9637 6350
www.plateway.com.au

Definitions

DLRV – Diesel Light Rail Vehicle, based on existing Kiwirail ADK-ADB narrow gauge railcars. A current light rail equivalent would include, for example, the Stadler GTW diesel powered light rail vehicles, suitable for operation on lightly laid rail and for street running.

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

OT – OpenTrack rail system modelling software.

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

Dwell time – Time at each stop (not included in sectional run times).

Unit 6, 3 Sutherland Street
Clyde NSW 2142
Phone + 61 2 9637 5830
Fax + 61 2 9637 6350
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Train Sectional Run Times – Scenarios 1 and 2

Hobart-Claremont Sectional Run Times – 45 kph maximum speed

Locality	Distance Km	DLRV OT SRT mins	DLRV Timetable SRT mins (including dwell time)	ELRV OT SRT mins	ELRV Timetable SRT mins (including dwell time)
Hobart	0	-	-	-	-
New Town	4.7	7:58	8.5	7:51	8.3
Moonah	5.9	3:55	4.5	3:48	4.3
Derwent Park	7.4	2:46	2.5	2:37	2.3
Glenorchy	9	2:23	3.5	2:15	2.8
Berriedale	11.9	4:22	4.5	4:10	4.3
Claremont	14.7	5:04	6	4:54	5.3
TOTAL			29.5		27.3

Unit 6, 3 Sutherland Street
Clyde NSW 2142
Phone + 61 2 9637 5830
Fax + 61 2 9637 6350
www.plateway.com.au

Claremont-Hobart Sectional Run Times – 45 kph maximum speed

Locality	Distance	DLRV OT SRT mins	DLRV Timetable SRT mins (including dwell time)	ELRV OT SRT mins	ELRV Timetable SRT mins
Claremont	14.7	-	-	-	-
Berriedale	11.9	4:57	5.5	4:48	5.3
Glenorchy	9	4:25	5	4:11	4.6
Derwent Park	7.4	2:24	3	2:15	2.6
Moonah	5.9	2:45	3.5	2:34	3
New Town	4.7	3:55	4.5	3:48	3.3
Hobart	0	8:05	8	7:58	8.3
TOTAL			29.5		27.1

Based on the OpenTrack data in scenarios 1 and 2 it was concluded that, in order to efficiently operate a 15 minute interval service as described in the brief, the sectional run times approaching 30 minutes would not be conducive to an efficient use of equipment. A second set of scenarios were run using the assumption that track had a stricter maintenance regime to allow running at 60 kph.

Train Sectional Run Times – Scenarios 3 and 4

Hobart-Claremont Sectional Run Times – 60 kph maximum speed

Locality	**Distance Km**	**DLRV OT SRT mins**	**DLRV Timetable SRT mins (including dwell time)**	**ELRV OT SRT mins**	**ELRV Timetable SRT mins**
Hobart	0	-	-	-	-
New Town	4.7	6:46	7.5	6:28	7
Moonah	5.9	1:58	2.5	1:38	2
Derwent Park	7.4	2:24	3	2:11	2.5
Glenorchy	9	2:10	2.5	1:53	2.3
Berriedale	11.9	3:35	4	3:16	3.6
Claremont	14.7	3:55	4	3:29	4
TOTAL			23.5		21.4

Unit 6, 3 Sutherland Street
Clyde NSW 2142
Phone + 61 2 9637 5830
Fax + 61 2 9637 6350
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Claremont-Hobart Sectional Run Times – 60 kph maximum speed

Locality	Distance	DLRV OT SRT mins	DLRV Timetable SRT mins (including dwell time)	ELRV OT SRT mins	ELRV Timetable SRT mins
Claremont	14.7	-	-	-	-
Berriedale	11.9	3:41	4	3:25	4
Glenorchy	9	3:43	4	3:17	3.6
Derwent Park	7.4	2:21	3	2:03	2.5
Moonah	5.9	2:21	3	1:56	2.3
New Town	4.7	1:53	2.5	1:41	2
Hobart	0	6:53	7	6:34	7
TOTAL			23.5		21.4

Plateway

Unit 6, 3 Sutherland Street
Clyde NSW 2142
Phone + 61 2 9637 5830
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Viriato Timetable Model

The Viriato software was used to determine optimum crossing loop sites on the single track and derive a timetable. It is considered ideal that crossing loops should be co-located with passenger halts to assist in minimsing time lost for operational purposes enroute. Crossing loops also need to be placed at regular intervals to allow services to pass each other on the single track in order to:

- Meet the headway demanded in the timetable
- Ensure a high level of reliability
- Provide for minimal time wasted waiting for other services to cross
- Maximise flexibility in case of equipment or infrastructure failure.

A terminating road was assumed to exist at both termini.

Iterations

The timetable was modelled using the DLRV run times and line speeds as used in the OpenTrack model, with the following iterations:

Iteration	Max Speed	DLRV	ELRV	Departures from both termini at the same time after each hour	Departures at the outer terminus after a minimum turnaround	Number of loops	Equipment sets required
1	45	√		√		3	6
2	45	√			√	4	5
3	45	√				Not assessed	
4	60	√		√		3	5
5	60+	√			√	3	4

Iterations 1 and 2 were used to determine if there were logical places for crossing loops, differentiating between departures from both termini being the same after each hour at each place, or, at the outer end, the service returning after a minimum turnaround period. The iterations suggested that, given the running times between halts, uneven spacing would make it difficult to co-locate loops and passenger halts. Furthermore, unnecessary operational time would need to be built into the timetable to effect a consistent timetable pattern, resulting in very slow end to end timings.

Unit 6, 3 Sutherland Street
Clyde NSW 2142
Phone + 61 2 9637 5830
Fax + 61 2 9637 6350
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Graphical timetables 1a and 2a indicate the number of vehicles and approximate locations of crossing loops required to provide the level of service described in the brief.

Iteration 3 demonstrates the complexity of building a timetable with the current running times. Returning trains (5 in all) were set up to show a cross at each of the five proposed passenger halts. Five loops, representing a loop at every intermediate passenger stop, could be considered in further iterations.

Further work needs to be done to determine locations of passenger stops and crossing loops, based on both evidence of passenger catchment and train operational performance.

For the terminating road in Hobart, consideration could be given to creating a loop in the old Hobart railway yard, located close to the “0” datum and 300 to 400 metres from the terminus. This would be relatively inexpensive to build as the existing track layout could be readily adapted for this purpose.

After iterations 1 to 3, additional assumptions were considered. Hence:

- In iteration 4 the railway was assumed upgraded to 60 kph maximum speed; and
- In iteration 5 the railway was assumed upgraded to a level that allowed for its historical running times to be replicated, approximately 22 minutes between Hobart and Claremont for a diesel multiple unit.

Unit 6, 3 Sutherland Street
Clyde NSW 2142
Phone + 61 2 9637 5830
Fax + 61 2 9637 6350
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Conclusions

The following summarises the preliminary conclusions that can be drawn from the OpenTrack and Viriato timetable models:

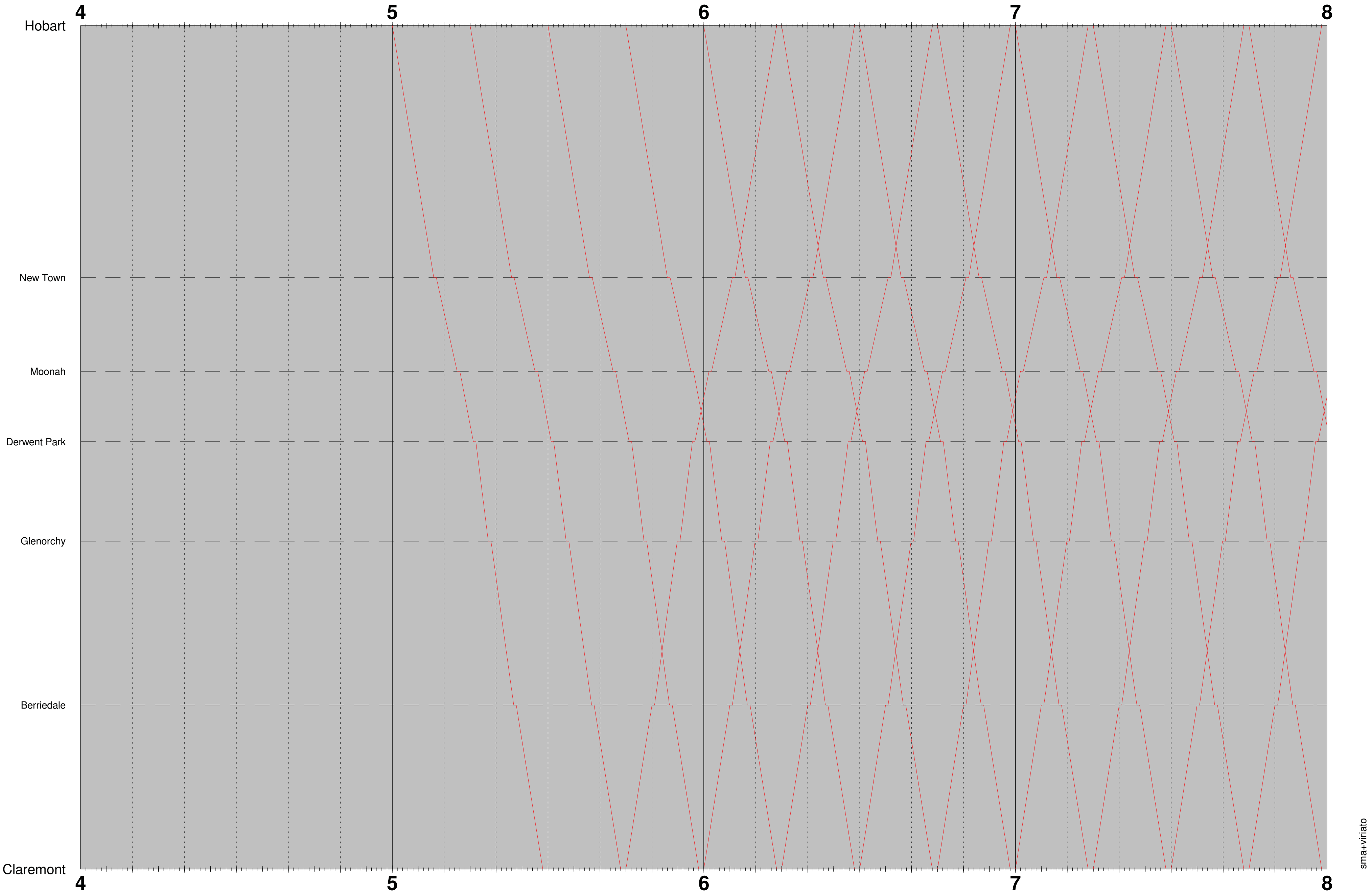
Conclusion	Iteration(s)	Attachment
Maintenance of maximum track speed around 45 kph creates equipment inefficiencies because the equipment cannot run out and back within an hour.	1, 2, 3	Graphical timetables 1, 2, 3
At current line speeds, to achieve even departure patterns from both termini you need 6 vehicles and 3 crossing loops to operate the service. At current line speeds, to achieve an even pattern but with different times at each termini you need 5 vehicles and 4 crossing loops.	1a, 2a	Graphical timetables 1a and 2a
Operational efficiency increases as sectional run times decrease, especially where run times allow an equipment cycle of two trips per hour. At higher line speeds, to achieve even departure patterns from both termini you need 5 vehicles and 3 crossing loops to operate the service. At historically high line speeds, to achieve an even pattern but with different times at each termini you need 4 vehicles and 3 crossing loops.	4,5	Graphical timetables 4, 5
Co-located loops at New Town, Derwent Park and Berriedale are operationally efficient where run times are faster.	4	Graphical timetable 4
Engineering parameters would need to be developed for an additional loop, either in or near the old Hobart yard if the assumptions of Iteration 5 were considered.	5	Graphical timetable 5

Attachments

Graphical timetables iterations 1, 2, 3, 4, 5
OpenTrack data

1: Hobart-Claremont

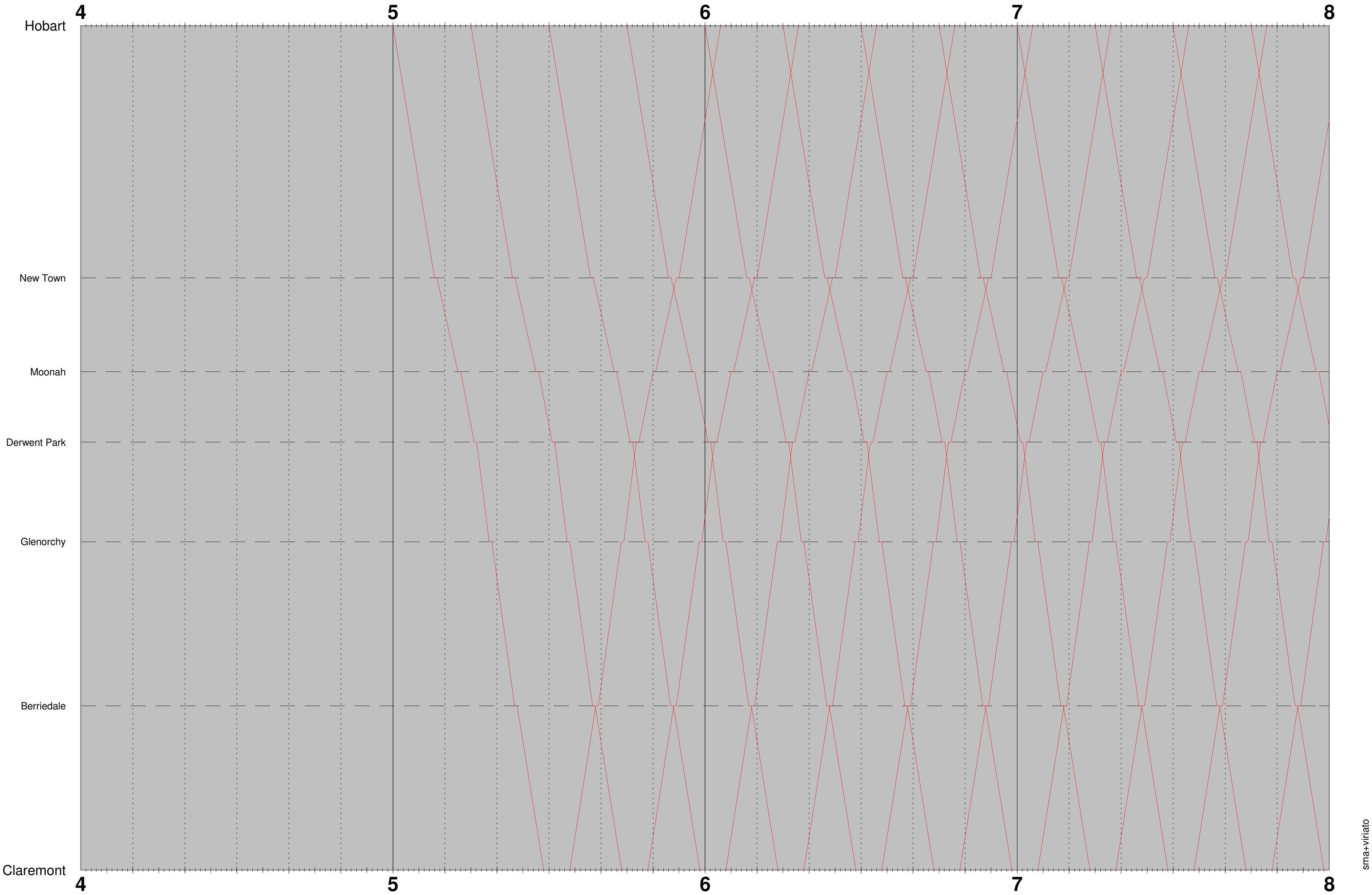
Iteration 1/DLRV (Equal departures)

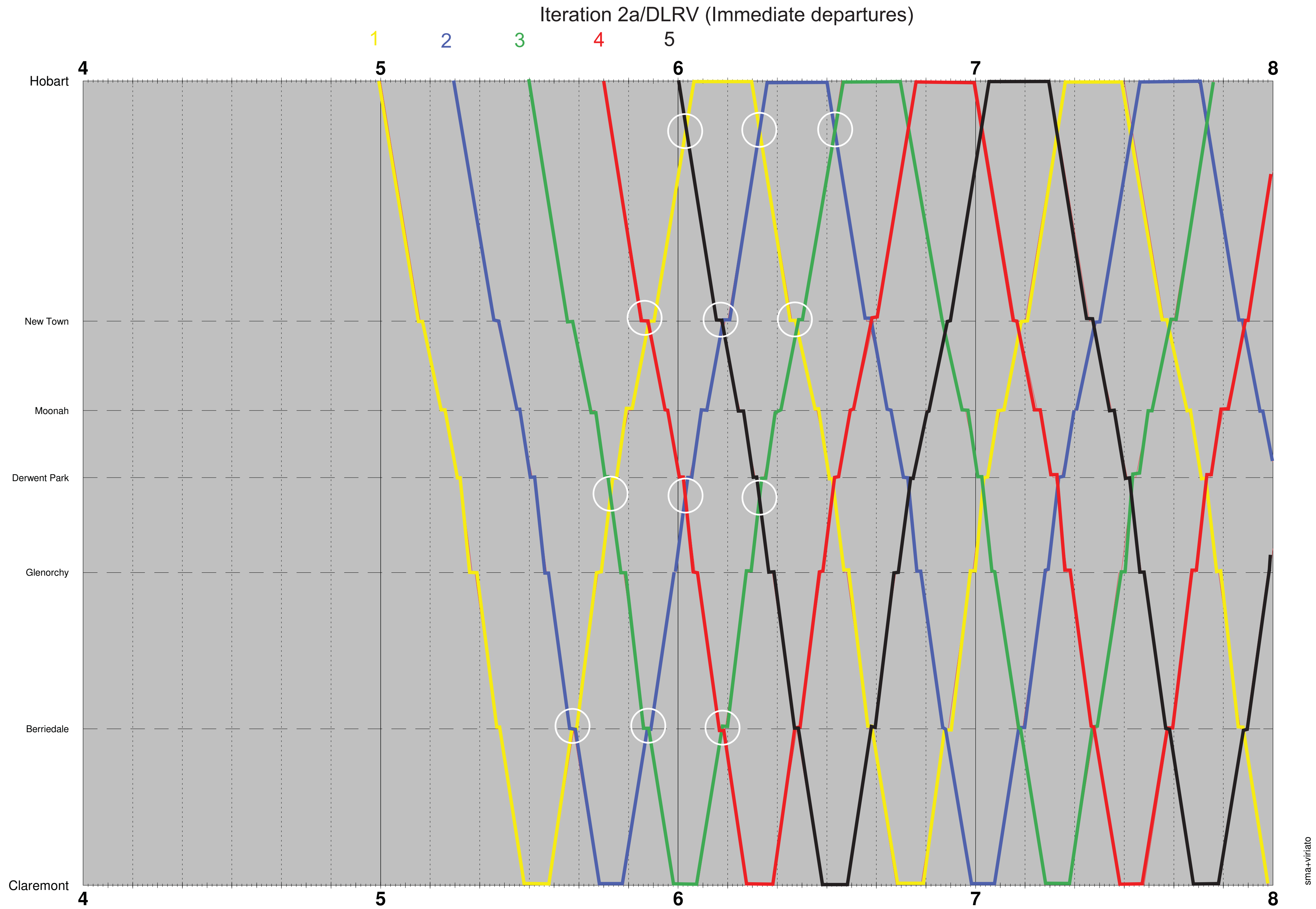


Iteration 1a/DLRV (Equal departures)

1: Hobart-Claremont

Iteration 2/DLRV (Immediate departures)



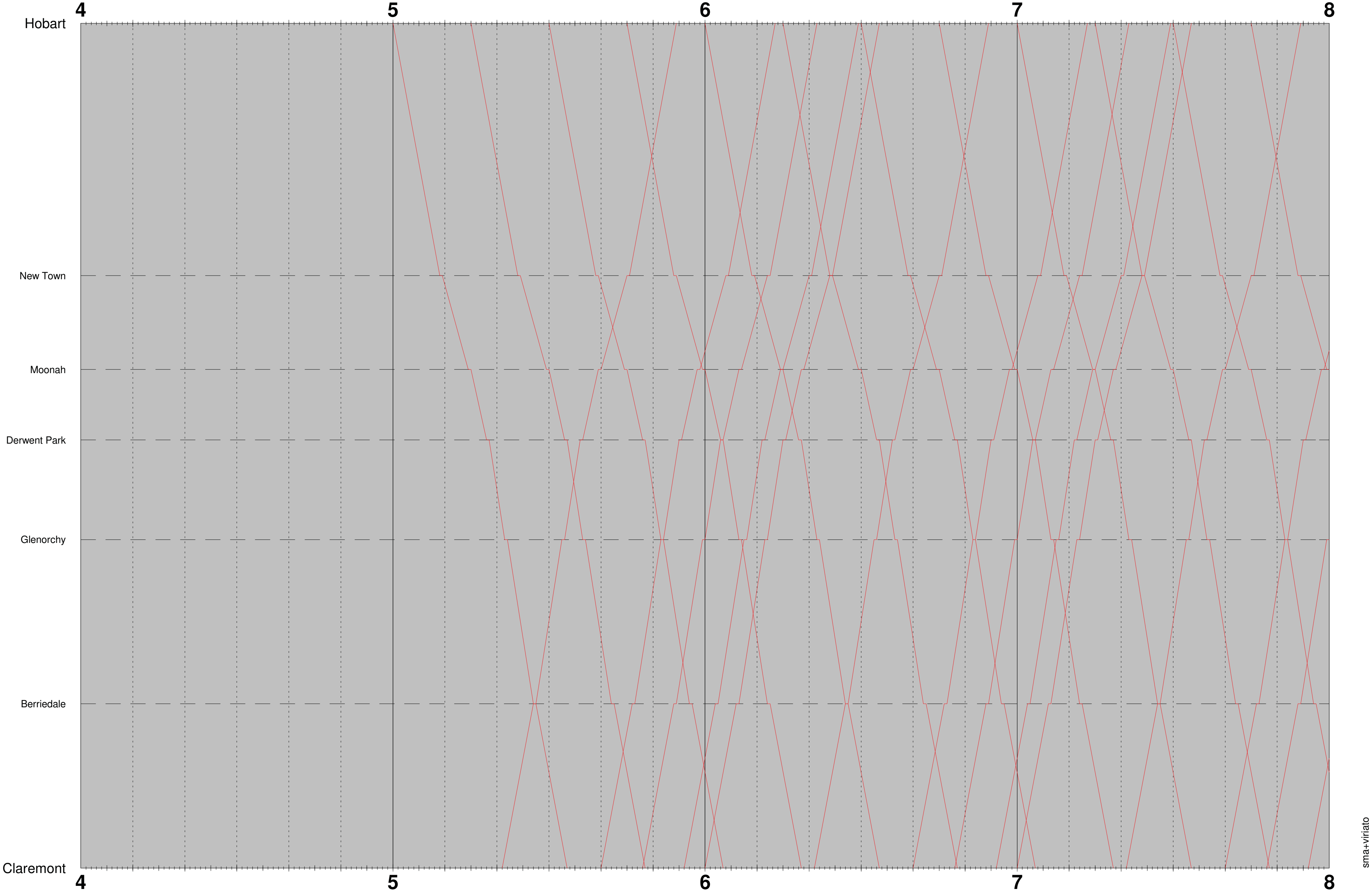


Iteration 2a/DLRV (Immediate departures)
1
2
3
4
5
4
5
6
7
8
Hobart
New Town
Moonah
Derwent Park
Glenorchy
Berriedale
Claremont
sma+viriato

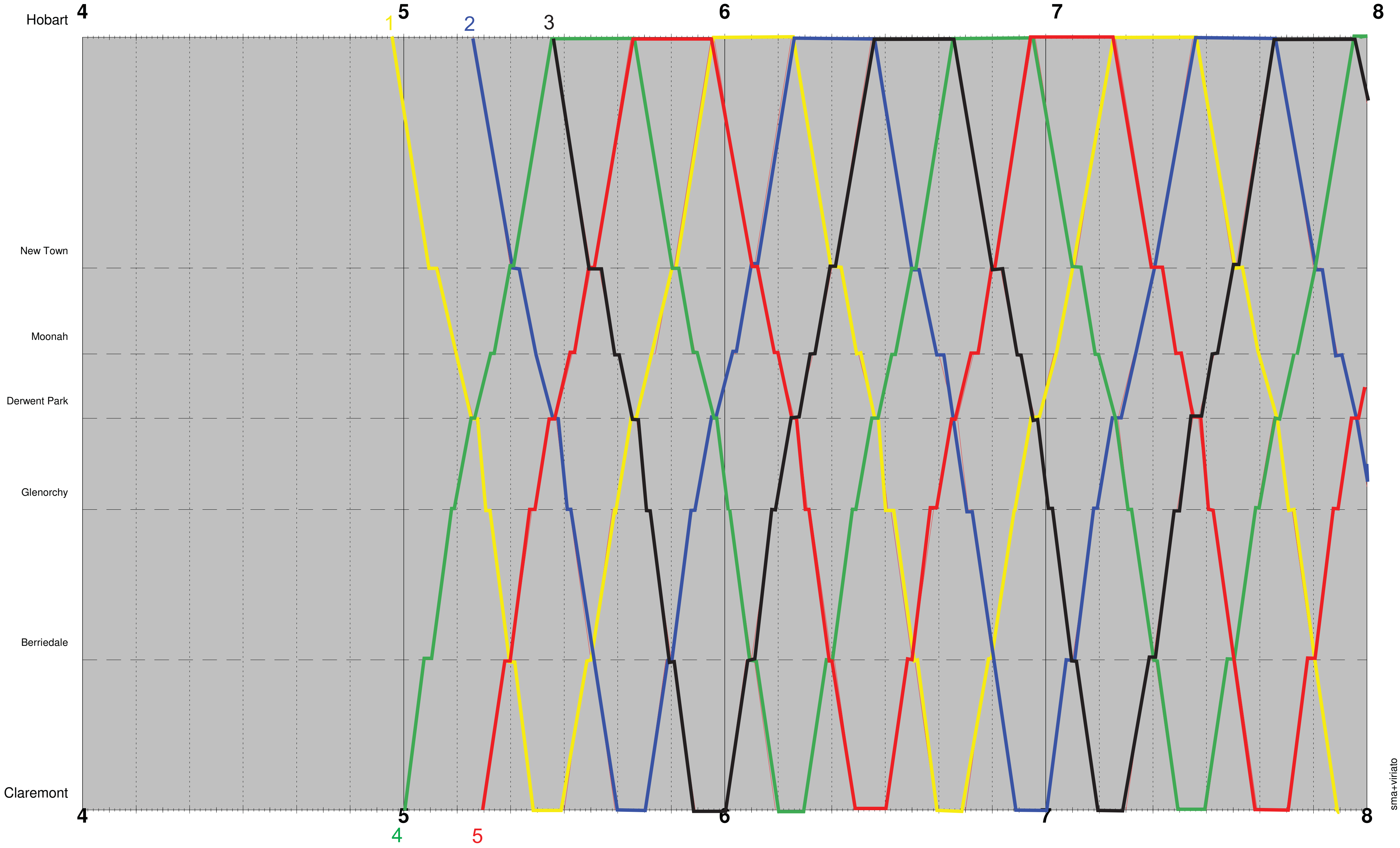
1: Hobart-Claremont

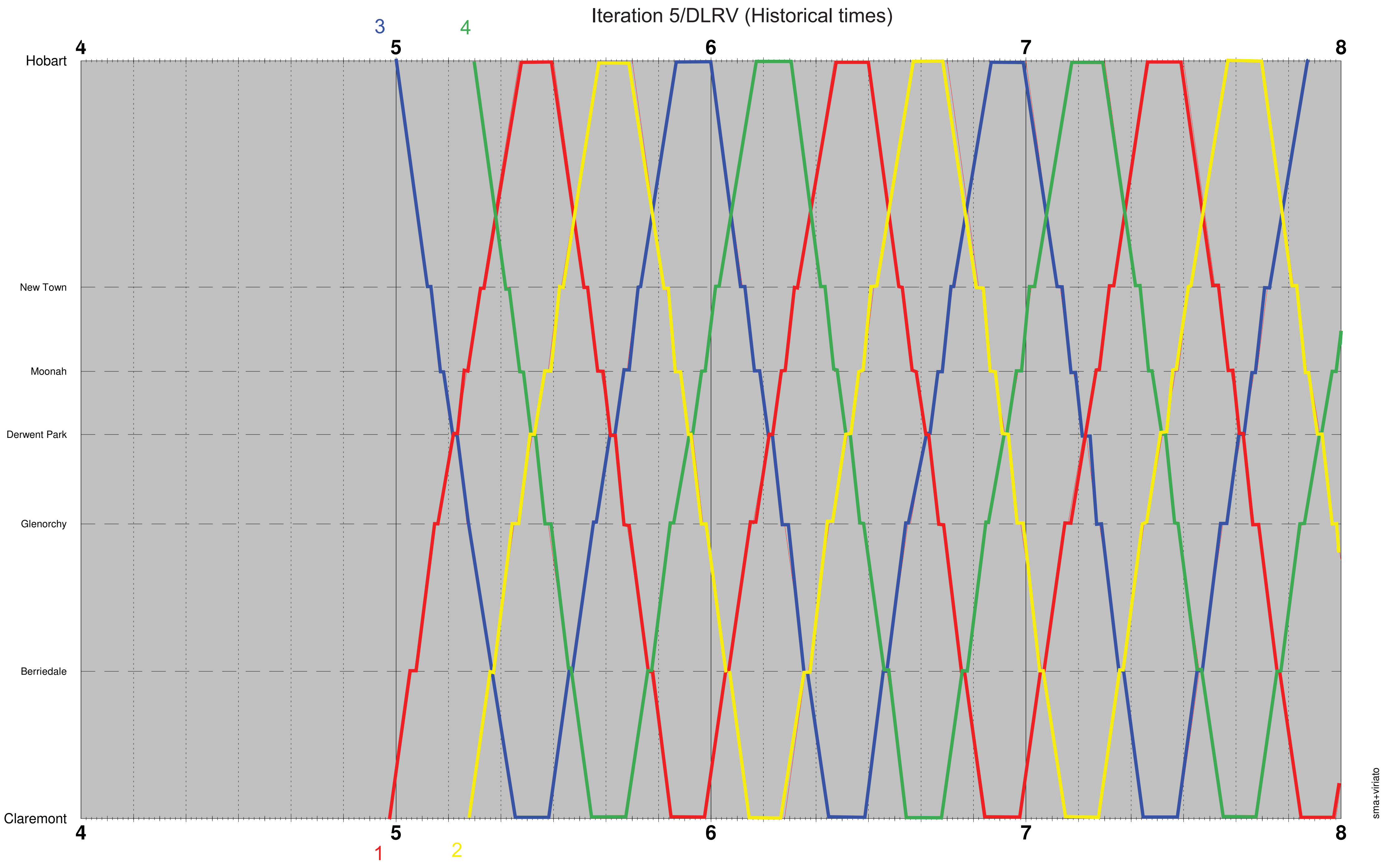
Iteration 3/DLRV (Loop assessment existing speeds)

Timetable Period: , Day(s): <all>, Day Type: <all>



Iteration 4/DLRV





Iteration 5/DLRV (Historical times)
3
4
4
5
6
7
8
Hobart
New Town
Moonah
Derwent Park
Glenorchy
Berriedale
Claremont
4
5
6
7
8
1
2
sma+viriato

Unit 6, 3 Sutherland Street
Clyde NSW 2142
Phone + 61 2 9637 5830
Fax + 61 2 9637 6350
www.plateway.com.au

Attachment 1 OpenTrack Modelling Assumption Sheet

Project Details		
Client	Hyder	
Project	Hobart light rail study	
Budget (Quote or Standard)		
Project Purpose & Outcomes		
Run Times Required	Best (Shortest) Possible ☐	Typical Average Achievable ☒
Route	Hobart to Claremont	
Date of TSRs		
New Consists Required?	No ☒ Yes ☐	

FOR CONFIRMATION

Train Driving Style: These assumptions will be set depending if you have previously selected ***Best*** (fastest) or ***Typical*** driving style. If you want to further amend them please indicate below:

Options	**Typical** ☒	**Best** ☐	**Amend**	***Other Value***
Max. Tractive Effort	97%	100%	☐	
Braking Method	Dynamic	Air/Dynamic	☐	
Braking Rates	Flexity: $-0.6m/s^2$ DMU: $-0.6m/s^2$		☐	
Other Handling Assumptions	Normal	Aggressive	☐	

Unless specified otherwise the model will be run with the following default assumptions. Please show any amendments you require.

Train Characteristics - Technical		**Amend**	***Amended Value***
Resistance Factor (Strahl Formula)	3.2999 (for both Flexity & DMU)	☐	
Rotating Mass	1.0599 (for both Flexity & DMU)	☐	

Courses		**Amend**	***Amended Value***
Timetable Version	N/A (single train only)	☐	
Stop Dwells	Flexity tram: 20 seconds 2 car DMU: 30 seconds	☐	
Staff/TOW Stops?	Train stops at staff change zero dwell	☐	

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Loops	Trains run on main line, except where stopping in loops as listed.	☐	

Signalling & Safeworking		Amend	*Amended Value*
Safeworking System	N/A (single train only)	☐	
Default Signal Sighting Distance	5,000m	☐	
Train Operation Rules	N/A (single train only)	☐	
Priority Rules (if any)	None (single consist)	☐	
Road Reservation (Sections)	N/A	☐	
Speed Board Treatment	End of train clears speed board before accelerating.	☐	

Delays		Amend	*Amended Value*
TSRs	None	☐	
Other Track Delays	None	☐	
Rollingstock Delays	None	☐	
Departure Delays	None	☐	

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TECHNICAL DETAILS (PLATEWAY USE)

Project Details		
Simulation Date	28 April to 2 May 2011	
OpenTrack Version	V1.6.4	
Technician	N/A	
Modeller	Rodney Allan	1/05/2011
Final Review	David Lewis	2/05/2011

Sure

Infrastructure Data	
Base Model	Hobart Light Rail
Model Description	Single track Hobart (Mawson Place) to Claremont built from client supplied data
Date of Model	28 April 2011
Variations Required	1) Hobart to Claremont with speed limits according to client supplied document “Speeds Limit measurement august 09.xls. 2) Hobart to Claremont with line speed upgraded to 60 km/h.
Route Length	Mawson Place (Hobart) to Yards (Hobart): 0.340 km Yards (Hobart) to Claremont: 14.700 km

Temporary Speed Restrictions	
No. of TSRs	N/A
TSR Date	N/A

Simulation Details	
Calculation Frequency	1s
Manual Interventions	N/A
Iterations	N/A
Random Number Seeding	N/A
Run Outputs	• Tables of sectional runtimes • Performance summary graphs

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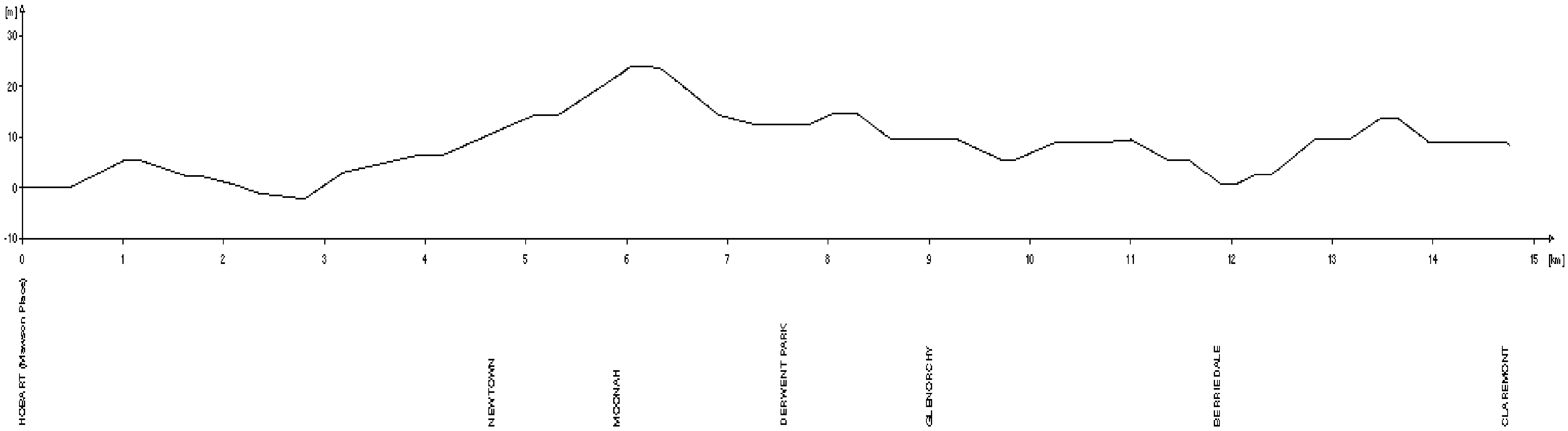
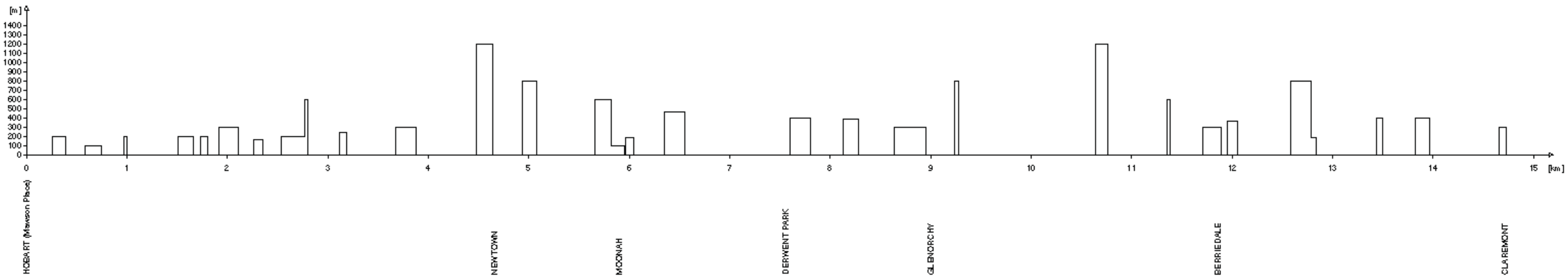
Hobart to Claremont
Altitude vs. Distance



Curve Radius vs. Distance



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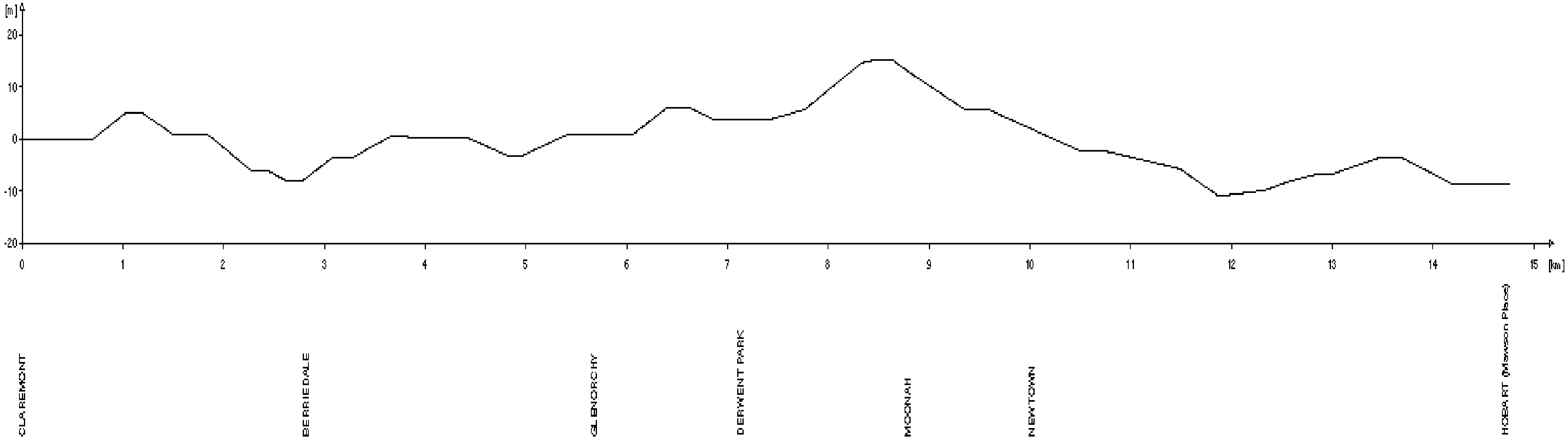
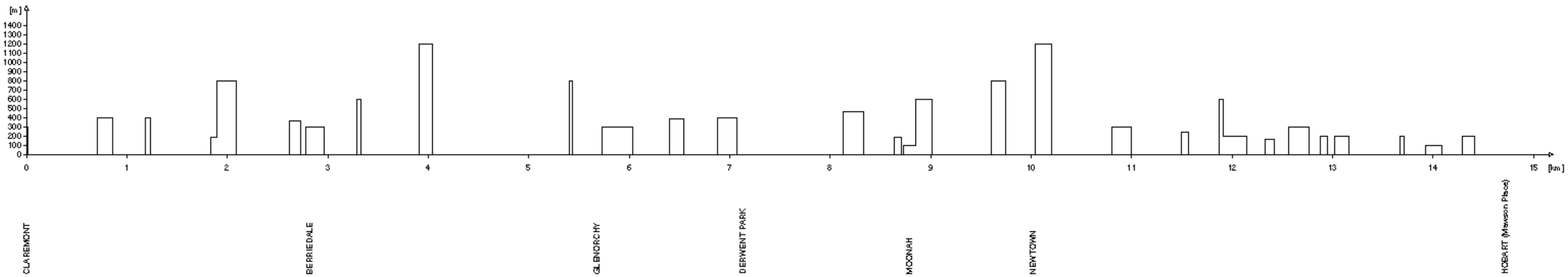
Claremont to Hobart
Altitude vs. Distance



Curve Radius vs. Distance



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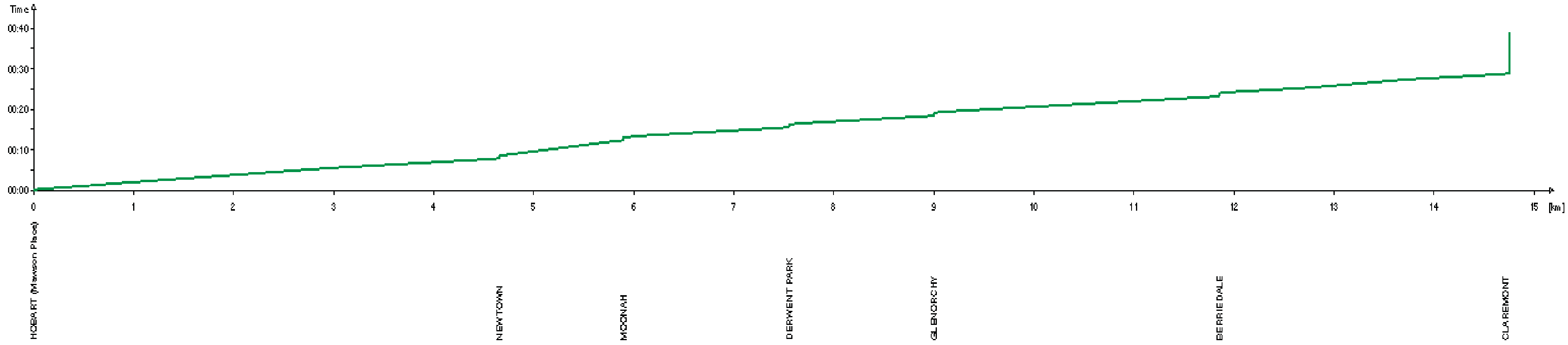
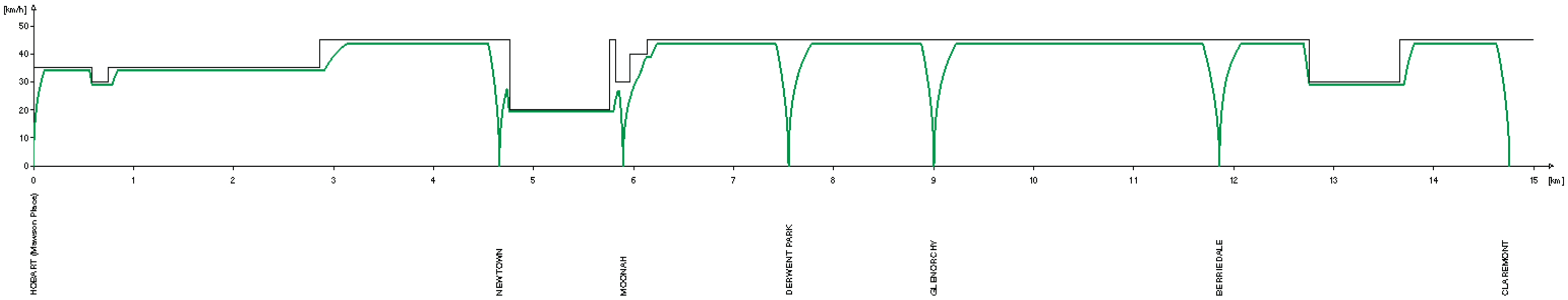
Scenario 1: Simulation physics output graphs for Hobart to Claremont with DLRV at 97% Performance at Current Speed Limit of 45 kph.

The following graphs show the time, speed, altitude and curve radii output for the case of running a 2 car DMU (ADK ADB) from Hobart (Mawson place) to Claremont.

Time vs. Distance



Speed vs. Distance



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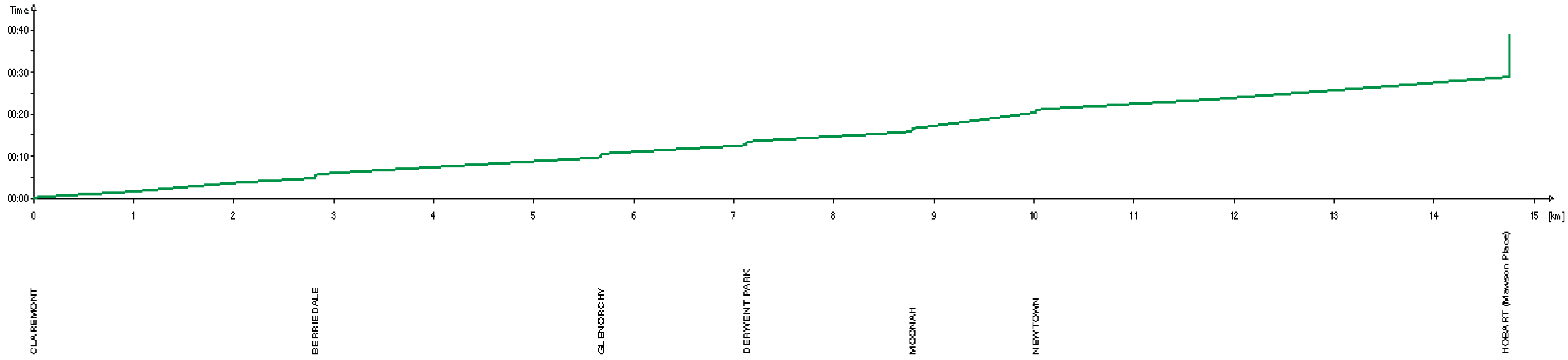
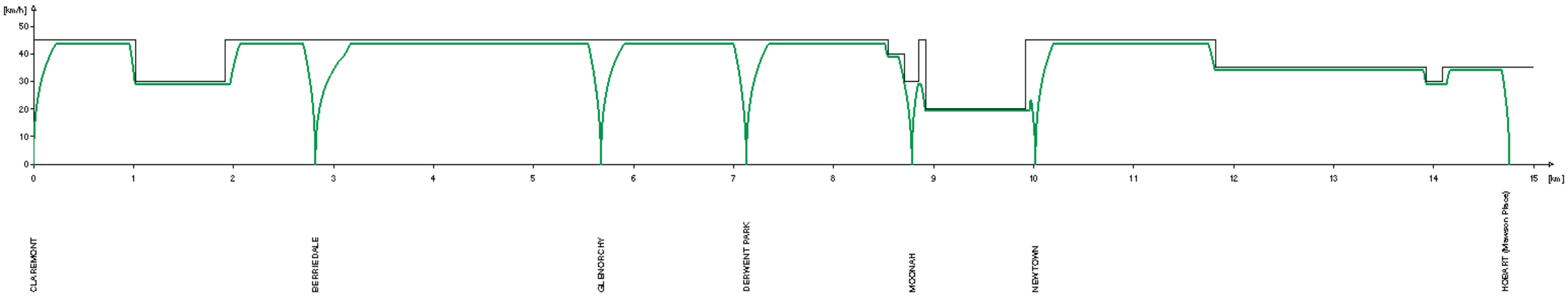
Scenario 1:Simulation physics output graphs for Claremont to Hobart with DLRV at 97% Performance at Current Speed Limit of 45kph.

The following graphs show the time, speed, altitude and curve radii output for the case of running a 2 car DMU (ADK ADB) from Claremont to Hobart (Mawson place). Note that the horizontal axis is distance travelled not kilometrage.

Time vs. Distance



Speed vs. Distance



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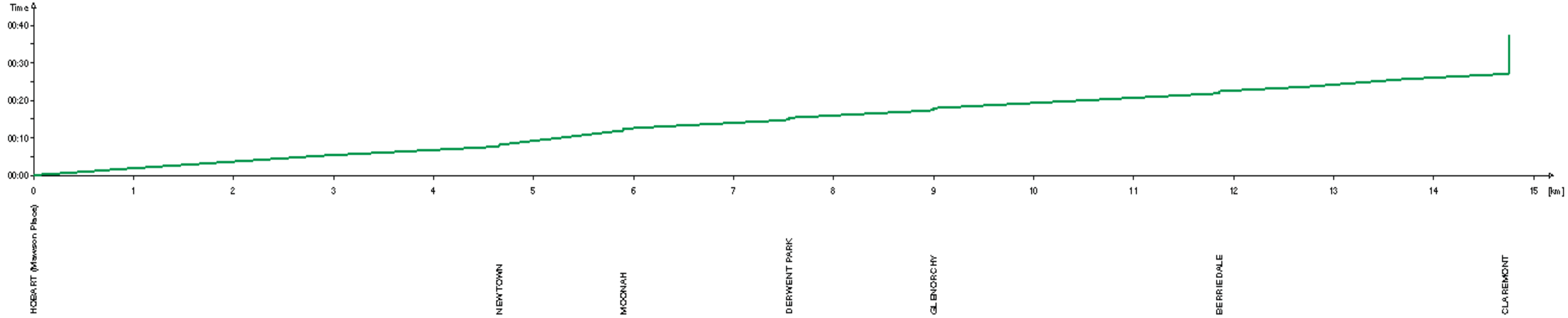
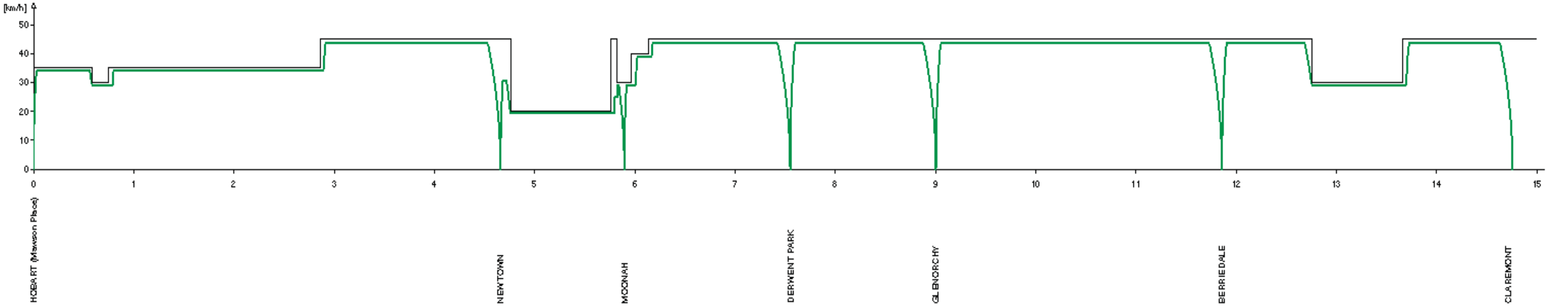
Scenario 2: Simulation physics output graphs for Hobart to Claremont with ELRV (Flexity Tram) at 97% Performance at Current Speed Limit of 45kph

The following graphs show the time, speed, altitude and curve radii output for the case of running a Flexity tram from Hobart (Mawson place) to Claremont.

Time vs. Distance



Speed vs. Distance



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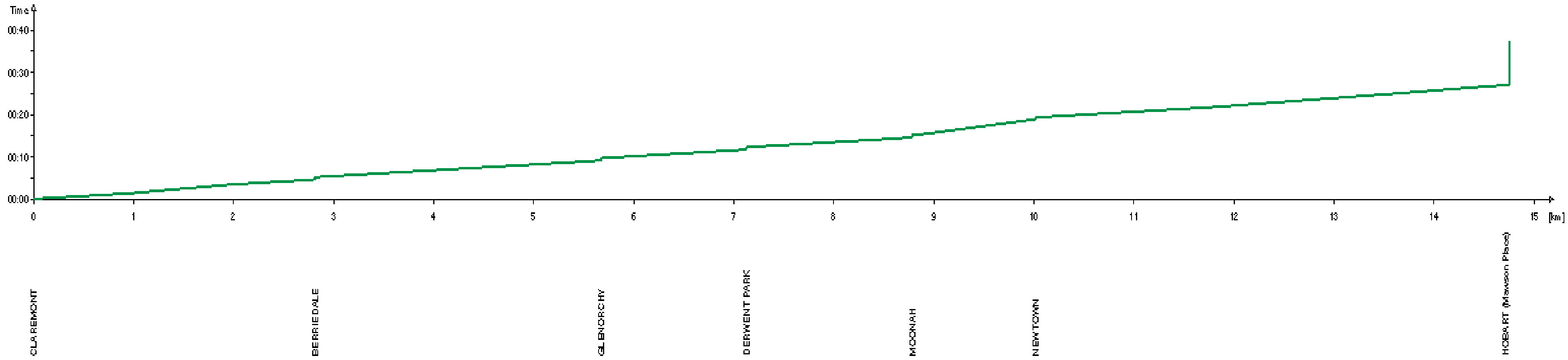
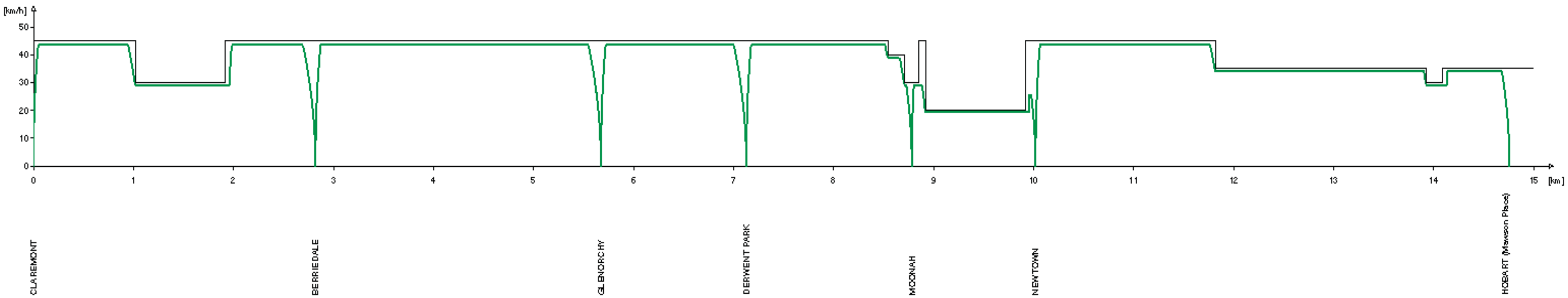
Scenario 2: Simulation physics output graphs for Claremont to Hobart with ELRV(Flexity Tram) at 97% Performance at Current Speed Limit of 45kph

The following graphs show the time, speed, altitude and curve radii output for the case of running a Flexity tram from Hobart (Mawson place) to Claremont. Note that the horizontal axis is distance travelled not kilometrage.

Time vs. Distance



Speed vs. Distance



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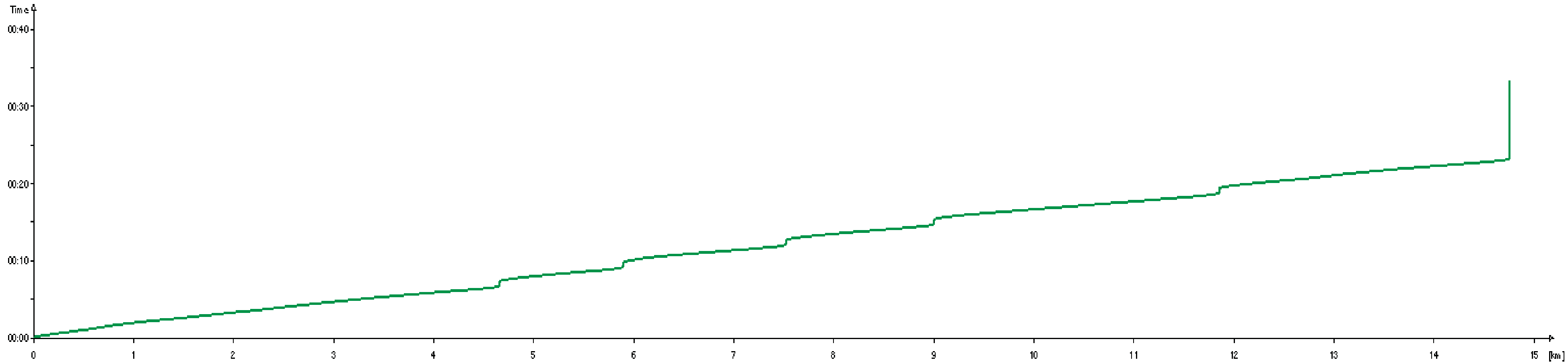
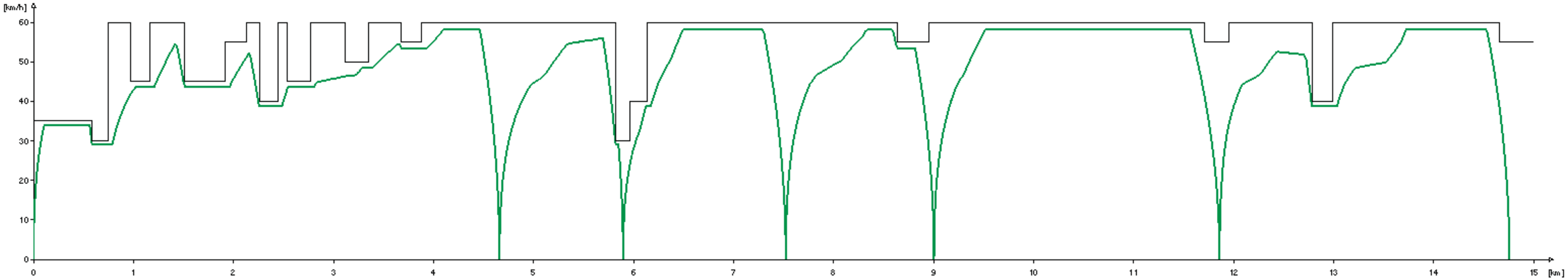
Scenario 3: Simulation physics output graphs for Hobart to Claremont with DLRV at 97% Performance with Track Upgraded to 60km/h Line Speed

The following graphs show the time, speed, altitude and curve radii output for the case of running a 2 car DMU (ADK ADB) from Hobart (Mawson place) to Claremont.

Time vs. Distance



Speed vs. Distance



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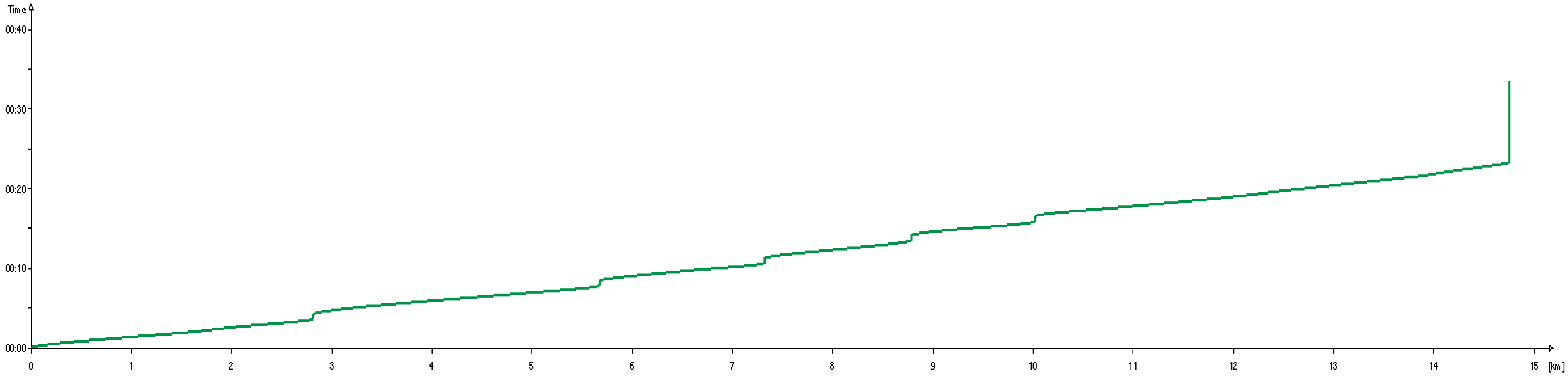
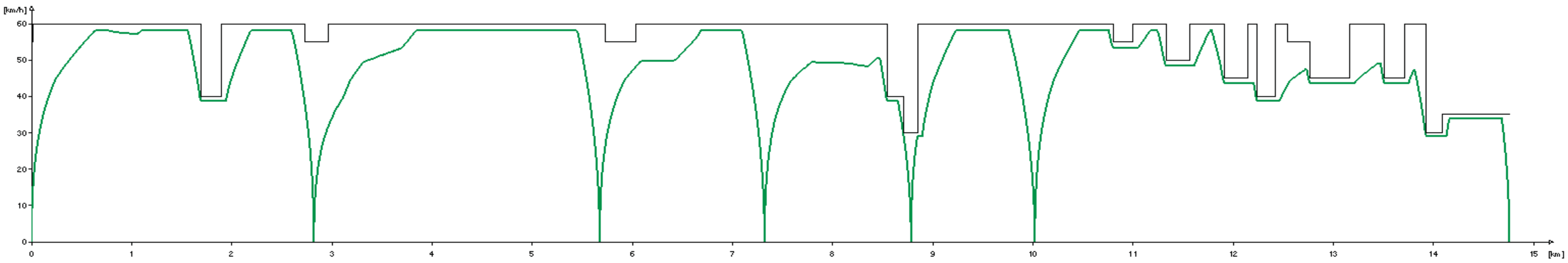
Scenario 3: Simulation physics output graphs for Claremont to Hobart with DLRV at 97% Performance with Track Upgraded to 60km/h Line Speed

The following graphs show the time, speed, altitude and curve radii output for the case of running a 2 car DMU (ADK ADB) from Claremont to Hobart (Mawson place). Note that the horizontal axis is distance travelled not kilometrage.

Time vs. Distance



Speed vs. Distance



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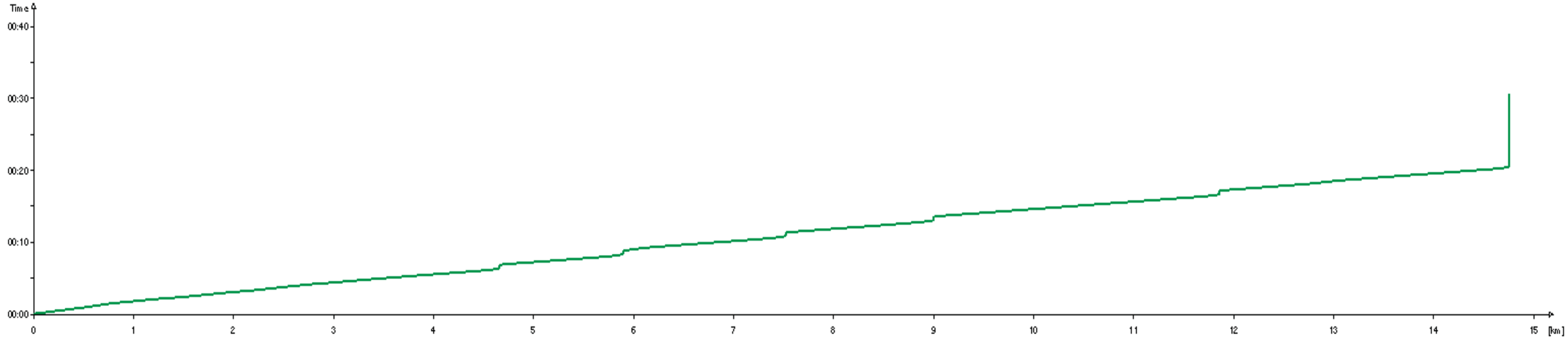
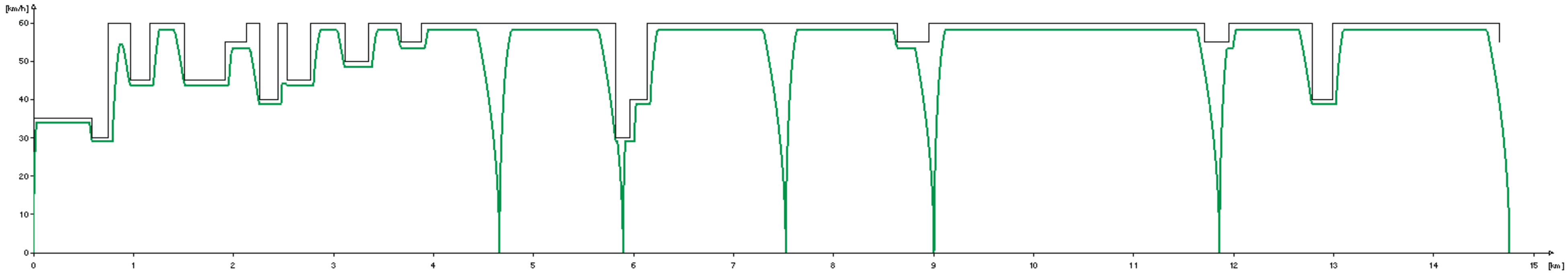
Scenario 4: Simulation physics output graphs for Hobart to Claremont with ELRV (Flexity Tram) at 97% Performance with Track Upgraded to 60km/h Line Speed

The following graphs show the time, speed, altitude and curve radii output for the case of running a Flexity tram from Hobart (Mawson place) to Claremont.

Time vs. Distance



Speed vs. Distance



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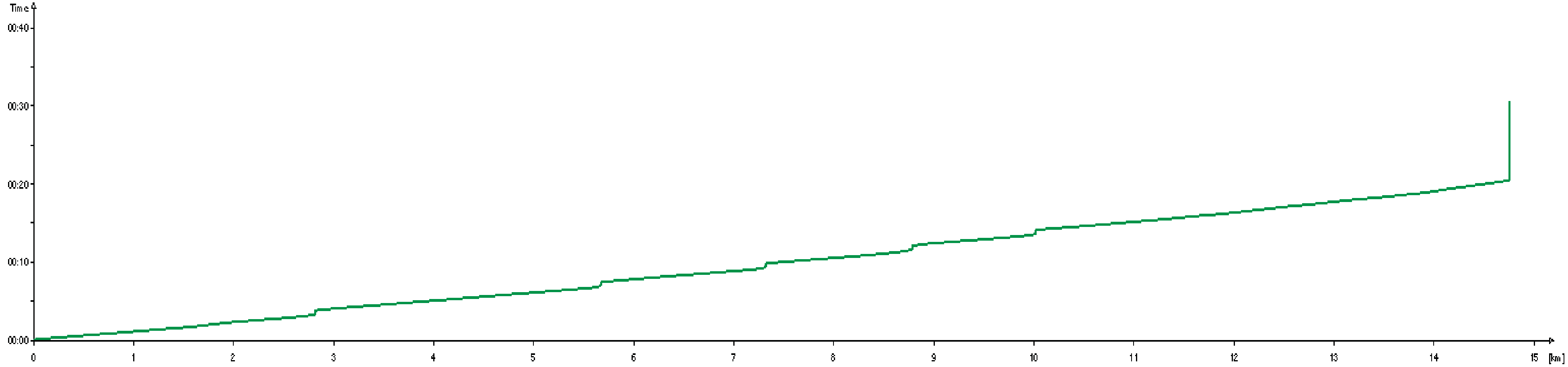
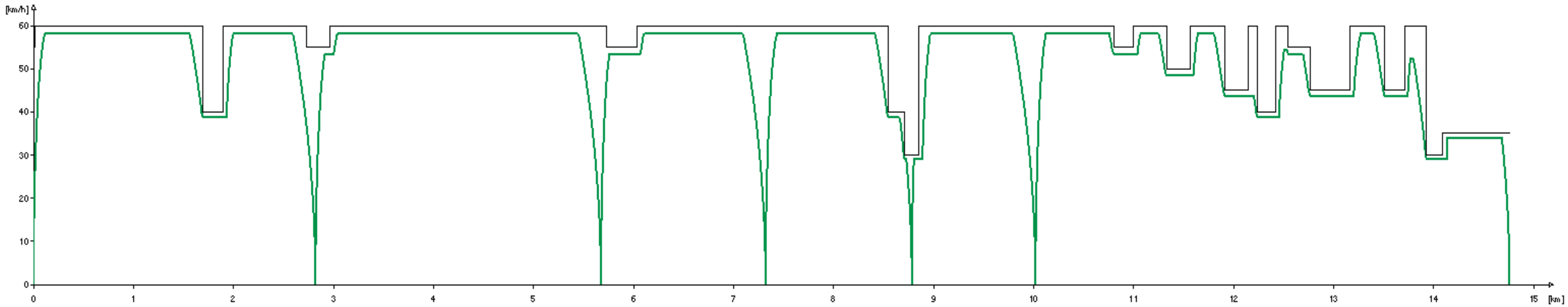
Scenario 4: Simulation physics output graphs for Claremont to Hobart with ELRV (Flexity Tram) at 97% Performance with Track Upgraded to 60km/h Line Speed

The following graphs show the time, speed, altitude and curve radii output for the case of running a Flexity tram from Hobart (Mawson place) to Claremont. Note that the horizontal axis is distance travelled not kilometrage.

Time vs. Distance



Speed vs. Distance



APPENDIX C – Technical Information / Electrification

Track Alignment Details

The information in the table below provides engineering parameters for the existing railway line between Claremont and Hobart. The information has been extracted from 'Diagram South Line KP S0 to KP S20, Issue 01 Dec 2009' as received from TasRail. The information provides the curve radii against kilometre chainage for the length of the rail line between Claremont and Hobart.

KILOMETRAGE FROM	KILOMETRAGE TO	RADIUS (M)
0.000	0.127	200
0.127	0.327	0
0.327	0.491	100
0.491	0.709	0
0.709	0.909	200
0.909	1.255	0
1.255	1.473	200
1.473	1.655	200
1.655	1.873	300
1.873	2.000	0
2.000	2.182	160
2.182	2.273	0
2.273	2.509	200
2.509	2.855	600
2.855	3.091	240
3.091	3.418	0
3.418	3.618	300
3.618	4.218	0
4.218	4.382	1200
4.382	4.673	0
4.673	4.836	800
4.836	5.400	0
5.400	5.564	600
5.564	5.709	100
5.709	5.873	180

KILOMETRAGE FROM	KILOMETRAGE TO	RADIUS (M)
5.873	6.091	0
6.091	6.291	460
6.291	7.345	0
7.345	7.545	400
7.545	7.564	
7.564	7.873	0
7.873	8.255	380
8.255	8.382	0
8.382	8.691	300
8.691	8.982	0
8.982	9.127	800
9.127	10.382	0
10.382	10.600	1200
10.600	11.091	0
11.091	11.455	600
11.455	11.691	300
11.691	11.927	360
11.927	12.327	0
12.327	12.527	800
12.527	12.727	180
12.727	13.182	0
13.182	13.564	400
13.564	13.982	400
13.982	14.400	0
14.400	14.800	300

Existing Gradients

The information in the table below provides engineering parameters for the existing railway line between Claremont and Hobart. The information has been extracted from 'Diagram South Line KP S0 to KP S20, Issue 1 Dec 2009' as received from TasRail. The information provides the grades against kilometre chainage for the length of the rail line between Claremont and Hobart.

KILOMETRAGE FROM	KILOMETRAGE TO	GRADIENT (1 IN X (M))
0.000	0.218	0
0.218	0.745	100
0.745	0.927	0
0.927	1.127	-149
1.127	1.400	-149
1.400	1.545	0
1.545	1.855	-198
1.855	2.091	-139
2.091	2.545	-413
2.545	2.927	73
2.927	3.691	218
3.691	3.927	0
3.927	4.818	115
4.818	5.055	0
5.055	5.691	77
5.691	5.782	64
5.782	5.945	0
5.945	6.091	-226
6.091	6.655	-63
6.655	7.018	-183
7.018	7.545	0
7.545	7.800	107

KILOMETRAGE FROM	KILOMETRAGE TO	GRADIENT (1 IN X (M))
7.800	8.018	0
8.018	8.364	-66
8.364	9.018	0
9.018	9.455	-110
9.455	9.600	0
9.600	10.000	116
10.000	10.509	0
10.509	10.745	541
10.745	11.127	-93
11.127	11.327	0
11.327	11.636	-68
11.636	11.800	0
11.800	11.982	96
11.982	12.145	0
12.145	12.582	62
12.582	12.927	0
12.927	13.236	75
13.236	13.382	0
13.382	13.709	-65
13.709	14.473	0
14.473	14.873	-77

Electrification Consideration

This section discusses and describes the feasibility of an Overhead system solution that could be adequate for the HLR.

General

There are different types of overhead light rail system (OHS) that have been used in Australia and around the world. Depending on the environment, history, maintenance regime and available recourses, one type is selected over another.

In general there are two types of OHS which are fixed system and auto tension system. Each system has its own advantages and disadvantages.

A fixed system is more suitable for the city area where more complex intersections exist and vandalism or damage could be an issue. The auto tension system can be adopted on a tangent track to compensate the temperature effect on the contact wire (excessive wire sags on the hot days) which will improve (increase) the structural spacing as a consequence.

Based on general knowledge and available information, this section will highlight and discuss the characteristics of the auto tension system.

Overhead System

The Overhead system (OHS) considered for this study consists of both contact and catenary wires with weight tension on the contact wire but a fixed catenary. This is a typical heavy rail system which is more cost effective than other typical OHS.

The figure below shows the typical catenary (fixed) /contact (weight tension) system. The catenary will support both wires using droppers between the supports.

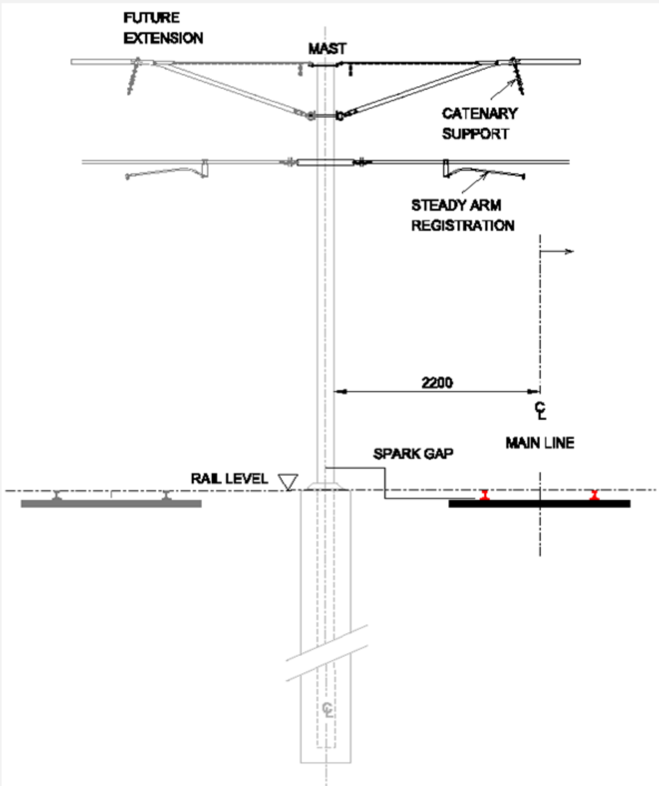


Figure 13: *Typical cross section*

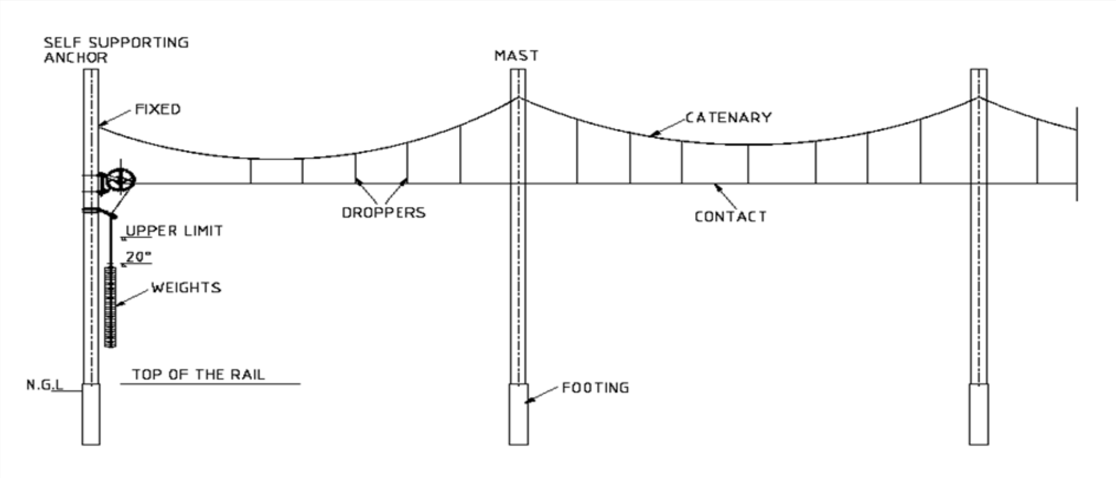


Figure 14: *Typical overhead weight tension system*

The masts would be positioned approximately two meters from the track centre line, supporting the catenary with a cantilever arm. The contact will be registered using a steady arm. This arrangement can allow for additional future track to utilise the existing infrastructure.

Electrical Requirements

The type of current and the nominal voltage, including permissible variations are significant characteristics of electrical requirements. Globally almost half of all electric railways use direct current traction (DC), the most common voltages being 600V and 750V.

Whilst the substation cost of adopting 1500V DC or AC system would be lower, this would be outweighed by the additional electrical protection and isolation costs. The purpose of the substation is to convert the AC supply which is typically 11,000 volts AC to 600 volts or 750 volts DC. The frequency of the substation locations is determined through analysis of the voltage drop and the peak demand in a particular section, availability of sites and locality of supply lines.

Overhead Parameters

The study was based on the following Overhead parameters;

- Length of the electrification: approximately, 15km, (500m of new tracks in CBD).
- Voltage: 600 -750 volts, DC.
- Tension length: 1000 – 1200m.
- Structures: Universal Column Section.
- Footings: Typical 4 - 5 m depth (Assuming 1 metre non-effective depth).
- Suspensions: Steady arm as registration.
- Feeders: Catenary wires will be used as feeder cables.
- Substations: Will be required at 3 - 4km intervals.

DETAILS	VALUE	UNIT
Span	60	m
Contact wire size	107	mm^2
Catenary wire size	100 -107	mm^2
Temperature range	0° - 50°	C
Contact wire tension @ 20°C	12000	N
Catenary wire tension @ 20°C	12000	N
Contact wire height range	4.80 - 5.70	m
Wind velocity	28	m/s
Coefficient of drag	1.0	-
Vehicle rolling	2	Degree
Pantograph carbon width	500	mm
Pantograph sway	185	mm
Max. Stagger	300	mm

Considerations

- The operational performance depends on
- The reliability of the power supply installation.
- Selecting carefully tested and/or proven components with a proven long service life, correct installation practices and an on-going maintenance regime during operational life.
- Availability of resources and equipment for maintenance purposes.
- Good local understanding of the system and not having to rely on overseas suppliers and expertise.

Standards and requirements

We believe that the Melbourne railway standards are more suitable for this study and they are:

- "Train Overhead Design Standards for the Electrification of New Routes" 1997 Issue 5.
- "Train Overhead Design Standards for the Construction of New Railway Overhead Works" 1997 Issue 3.
- Yarra Trams Overhead Construction Manual.
- The Electricity Safety (Network Assets) Regulations 1999, and/or Tasmanian regulatory standards and requirements.
- Steel Structures AS 4100.
- SAA Wiring Rules AS 3000.
- Concrete Structures AS 3600.
- Wind Loading AS 1170.2.

APPENDIX D – Risk Assessment

Risk Assessment

REF	CAUSATION (RISK)	FORESEEABILITY (LIKELIHOOD)	RI	PREVENTABILITY (RISK REDUCTION)	RI	COMMENTS
1	**STAKEHOLDERS**					
1.1	Federal Government (Infrastructure Australia)	Change of Government in project lifespan – paradigm shift	5D	Little that the DIER / Metro Tasmania can do to alleviate this risk	5D	
		Federal Government does not sign off on Project Plans	5D	Ensure that all Project Plans (e.g. EMP) meet or exceed Federal Government criteria and are approved before project start	5E	
1.2	State Government	Change of Government in project lifespan – paradigm shift	5D	Little that the DIER / Metro Tasmania can do to alleviate this risk	5D	
1.3	Local Government	Change of Local Council in project lifespan – paradigm shift	5D	Little that the DIER / Metro Tasmania can do to alleviate this risk	5D	
		Failure to get correct zoning for project. Areas are currently zoned as Heavy rail / Dock areas.	5B	Ensure correct zoning approval is obtained from Local Council prior to project start.	5E	
1.4	Heritage Tasmania / National Trust	Possibility of heritage / sacred sites within project area boundaries	5D	Ensure that Heritage Tasmania and/or National Trust clearance is obtained before project start	5E	
1.5	DIER / Metro Tasmania	DIER / Metro fail to obtain all relevant approvals, planning permission etc from stakeholders	5D	DIER / Metro Tasmania Management to ensure that all identified risks have been addressed and appropriate criteria met.	5D	
1.6	Metro Tasmania personnel	Inadequate communication / training leading to industrial disputes – loss of services and customer confidence	5B	Ensure all appropriate Metro Tasmania personnel and Trade Unions are fully aware of all design / operation proposals	5E	
1.7	Roads Authority	Inability to negotiate required upgrades with Road Authority at level crossings, bridges etc	4B	Negotiate applicable road access upgrades and / or realignments with Road Authority before the project starts	5E	
1.8	Residents' Groups	Opposition to project due to increased Light Rail (LRV) traffic, noise, pollution, reduction of amenities etc leading to project reappraisal	5B	Consult and negotiate with residents' associations. Provide Community newsletters and briefings	5E	

REF	CAUSATION (RISK)	FORESEEABILITY (LIKELIHOOD)	RI	PREVENTABILITY (RISK REDUCTION)	RI	COMMENTS
1.9	Public Transport Users Groups	Lack of support for project due to inadequate access to stops (lack of feeder bus routes, park & ride, taxi stands etc), perceived lack of services (e.g. greater than 30 minutes between scheduled services in off – peak periods), high level of fares for supplied services,	5B	Ensure Public Transport User Groups concerns are addressed in project assessments and designs Public meetings and newsletters in local communities	5E	
1.10	General public apathy	Car based lifestyle, failure to grasp implications of project, cost perceived to be a stumbling block	5B	Conduct major 'hearts and minds' campaigns stressing advantages and benefits of Light Rail to the wider community Public meetings and newsletters in local communities	5D	
1.11	Public Transport Coordination	Lack of coordination of timetables between various public transport modes (e.g. bus and LRV) leading to loss of public confidence in ability of project to deliver transport improvements	5B	Ensure an Authority is established to coordinate various means of public transport		
2	**ROAD TRAFFIC**					
2.1	Intersections	Verify that intersections can handle traffic delays due to increased Light rail Traffic	4A	a. Where appropriate Redesign current intersections layouts and traffic lights b. Acquire appropriate properties for road widening	3B	
2.2	Level crossings	Current level crossings (17 in no with flashing lights) have high level of incidents involving vehicles / goods trains.	5C	Consider: ▪ Add boom gates with traffic lights ▪ Retain existing booms/lights with effective road vehicle driver education program ▪ Grade separation	 5D 5D 5E	
2.3	On road running (Hobart Waterfront, Mawson Place)	Potential for LRV / vehicular traffic / pedestrian incidents	5B	Ensure track design provides adequate separation between LRV and other road users	5D	

REF	CAUSATION (RISK)	FORESEEABILITY (LIKELIHOOD)	RI	PREVENTABILITY (RISK REDUCTION)	RI	COMMENTS
3	**ENVIRONMENT**					
3.1	Contamination: land / river	Contaminated material on site.	4A	Ensure all affected areas are adequately surveyed and contaminants identified. Remedial action to be established and approved by the appropriate authorities before project construction starts.	3D	
3.2	Storm water	Contamination of waterways with storm water run off	4A	Ensure that potential pollution of waterways is minimised. Remedial action to be approved by the appropriate authorities before project construction starts	2D	
3.3	Underground Services	Existing underground services (e.g. sewers, water, telecoms etc) inadequately protected from increased rail traffic. Current rail bed may be unsuitable to protect services from damage from increased rail traffic	4C	Survey all underground services in the areas affected by the project and ensure that they are adequately protected from increased traffic before project construction starts	3E	If considered necessary, the relocation of underground services should be investigated
3.4	Overhead Services	Existing overhead services (e.g. electrical supply, telecoms etc) inadequately protected from possible OHE and rail traffic	4C	Survey all overhead services in the areas affected by the project and ensure that they are adequately protected from increased traffic before project construction starts	3E	If considered necessary, the relocation of overhead services should be investigated
3.5	Traffic noise	Noise from increased rail traffic affecting residential areas	4A	Consider noise barriers where appropriate. Consider noise reduction in proposed vehicles design	3A	
3.6	General pollution	General levels of pollution (e.g. litter) from rail activities, particular at stops Pollution from maintenance activities	3A 3A	Ensure adequate rubbish removal facilities / services. Education of Metro Tasmania personnel and general public Ensure maintenance activities minimise pollution. Education of Metro Tasmania maintenance personnel	3D 3D	
3.7	Environmental impacts	Impact of environmental conditions (heavy rain, sleet, snow, flood, fog electrical storms etc)	5B	System Design to cater for worst case environmental conditions (flash flooding, 1 in 100 year floods, blizzard conditions, thick fog, lightning strikes etc) affecting key infrastructure	5D	

REF	CAUSATION (RISK)	FORESEEABILITY (LIKELIHOOD)	RI	PREVENTABILITY (RISK REDUCTION)	RI	COMMENTS
4	Emergency Management					
4.1	Hazardous Chemicals / Dangerous Goods	Fuel / battery acid spillage from vehicles. Cleaning chemicals etc in Vehicle Maintenance Area	3B	Light rail vehicles to be electrically powered (OHE or battery) Ensure cleaning chemicals etc in Vehicle Detailing Area are as non-hazardous as possible	1D 1D	
4.2	Fire – rail vehicles	Loss of life due to internal fire spreading to adjacent carriages	5D	Ensure close Emergency Management cooperation with Emergency Services. Emergency Management Plans to be established. Ensure fire retardant materials are used	4D	
4.3	Fire – maintenance depot	Loss of depot due to fire internally or from external facilities	5D	Ensure close Emergency Management cooperation with adjacent facilities management and emergency services. Emergency Management Plans to be established. Hazardous Facility Management Plans to be updated where necessary to take depot into account	4D	
4.4	Vandalism	Break in to depot by vandals. Vandalism to rail vehicles, property damage. Vandalism to infrastructure, including OHE, communications, signals / level crossings etc leading to loss of life	5C	DIER / Metro Tasmania and Emergency Services to coordinate security requirements, e.g. secure fencing where appropriate, anti climbing devices, CCTV surveillance, irregular patrols etc	2D	
4.5	Terrorism	Terrorism attack on rail infrastructure possibly leading to total loss facilities	5D	DIER / Metro Tasmania, Emergency Management Services to introduce security requirements, e.g. secure fencing, CCTV surveillance, irregular patrols etc	5E	

REF	CAUSATION (RISK)	FORESEEABILITY (LIKELIHOOD)	RI	PREVENTABILITY (RISK REDUCTION)	RI	COMMENTS
5	**Infrastructure**					
5.1	Overhead equipment (if fitted)	Potential for electrocution with inadvertent contact /	4B	Design to current standards	4D	
		Isolation in emergency	4B	Ensure control system can isolate sections of track in an emergency Consider track feed with automatic activation of sections	4D 4E	
		Inadequate infrastructure – lack of power leading to reduced / cancelled services and loss of passenger confidence	4C	Ensure OHE infrastructure can meet projected and forecasted demand	4E	
		Damage from environment (high winds, snow, lightning strikes etc)	4B	Design to current standards	4D	
5.2	Signalling	Inadequate signalling / train order system provision.	5C	Ensure signalling designed to current standards. Consider single / double track / passing loops requirements. Consider power requirements – solar versus mains feed	5D	
		Vandalism to infrastructure	5C	Signalling equipment to be as vandal proof as far as possible. See also 4.4	5D	
5.4	Track infrastructure	Track design inadequate for projected services	4B	Consider single versus double track. If single track ensure adequate passing loops	4D	
5.5	Existing track	Existing track inadequate for proposed service. Rough ride, reduction / cancellation of services leading to loss of passenger confidence	4B	Ensure track construction is adequate for proposed services and passenger comfort Consider complete track renewal or road bed, sleeper improvements / replacement	4E	
5.5	Passenger access	Proposed LRV stop (7 proposed) design inadequate for projected numbers / DDA requirements. Lack of environmental protection in adverse weather conditions	4B	Ensure stop design meets DDA access requirements and platforms of adequate capacity for projected demand. Suitable passenger shelters provided	4D	
5.6	Vehicle tracking / communications	System Control unaware of LRV passenger or maintenance vehicle whereabouts, potential for collision / incidents, particularly on single track	5B	Ensure all LRV vehicles having suitable tracking and communication systems fitted.	5D	

REF	CAUSATION (RISK)	FORESEEABILITY (LIKELIHOOD)	RI	PREVENTABILITY (RISK REDUCTION)	RI	COMMENTS
5.7	System Control	Inadequate design / facilities leading to lack of control and coordination in normal and emergency situations	5B	Ensure system control facilities can meet normal and emergency scenarios without major loss of control. Maintain communication with Emergency Services	5D	Liaison with Emergency Services required
6	**LRVs**					
6.1	Vehicles inadequate for projected service levels	Loss or reduction of services. Loss of passenger confidence	4B	Ensure proposed vehicles meet projected service demand.	4D	
	Environment Impact on Vehicles	Vehicles unable to cope with environment – heavy rains, sleet, snow, high winds, freezing conditions etc leading to cancellation / reduction of services and loss of passenger confidence	5C	Design to consider worst case environmental impacts.	5D	
6.2	Vehicle propulsion	Environmental impacts, reduction / cancellation of services. Loss of passenger confidence)	4B	Consider vehicle propulsion: ▪ OHE – Consider visual impact, environmental impact ▪ Diesel – consider noise, pollution and environmental impact (carbon emissions) ▪ Battery – consider capacity, charging requirements ▪ Capacitor unit / induction loops – consider unproved technology, charging requirements ▪ Consider climate change potential ▪ Consider new versus used vehicles	4D	
6.3	Passenger environment	Vehicle design exposes passengers to excessive noise, extremes of temperature etc leading to loss of passenger confidence	4B	Ensure vehicle design meets noise reduction requirements and maintains an equitable temperature environment	4E	
6.4	LRV vehicle Gauge	Passenger and maintenance vehicles 'off-the-shelf' or used vehicles may have incorrect gauge for Hobart LRV	4C	Vehicles may have to be regauged causing increased cost and project delay Consider purpose built vehicles if costs of regauging are excessive	4C	

Risk Assessment Approach

The following is a Risk Assessment for the proposed Light Rail Vehicle system for Hobart to demonstrate the principles of due diligence. It is divided into six sections covering stakeholders, road traffic, environment, emergency management, infrastructure, and LRV vehicles. It identifies initial risk in these areas but does not attempt to provide an in-depth analysis.

The methodology that Hyder has found meets the requirements of due diligence is given in the following figure and discussed below.

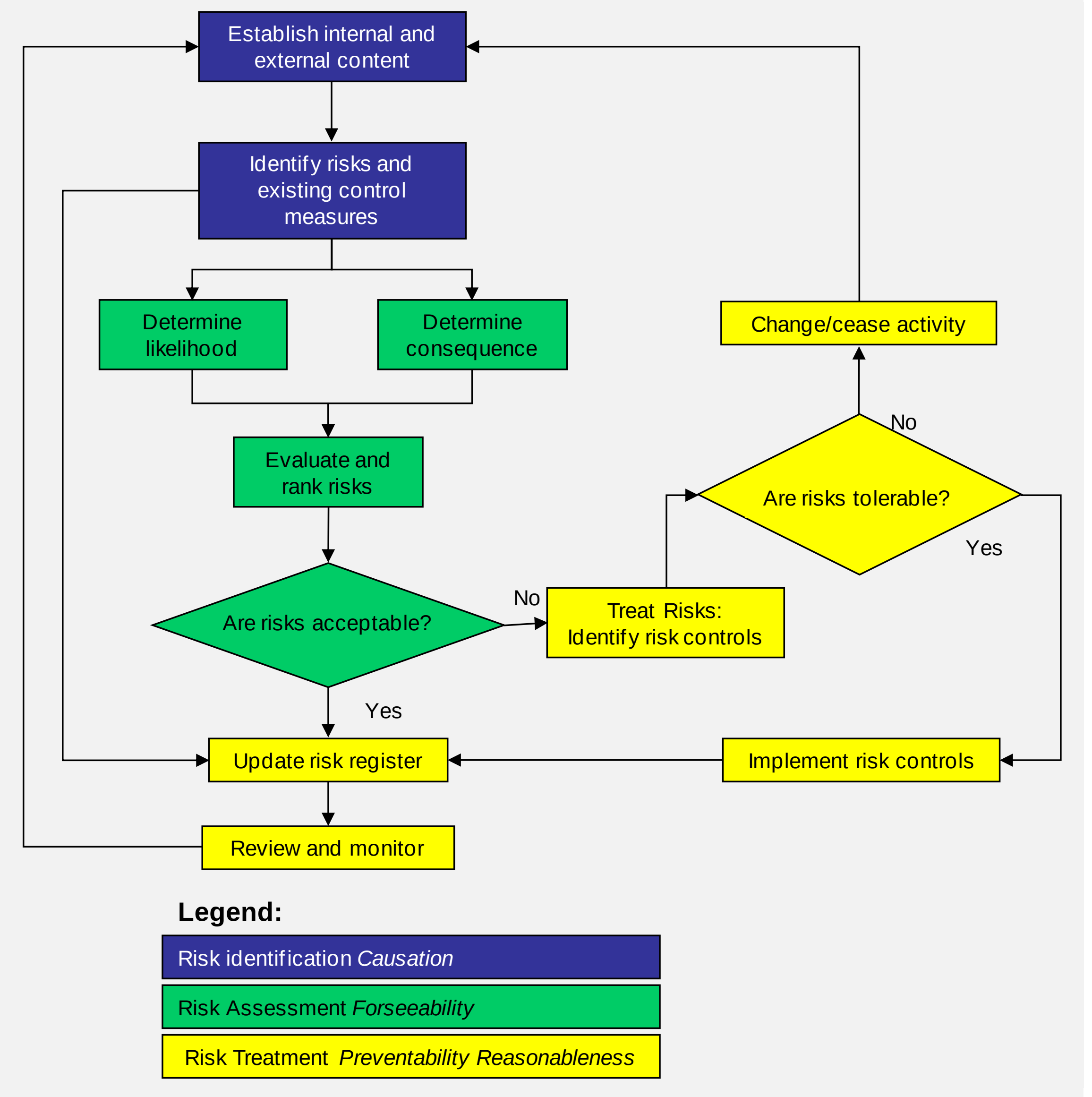


Figure 15: *Safety lifecycle*

1 **Concept and Design:** This step develops an understanding of the proposal sufficient to establish the due diligence principle of 'causation' i.e. is there a sufficient understanding of the Light Rail system and the operational environment?

2 **Hazard and Risk Analysis:** Safety is freedom from unacceptable risk of harm. Harm is understood in relation to human injury /death and/or damage to property and/or the environment, but what is 'acceptable'?' Risk is the effect of uncertainty on objectives and is often expressed in terms of consequences of an (unwanted) event and the associated likelihood of occurrence.

The first task is to determine the hazards and hazardous events in all modes of operation, for all reasonable foreseeable circumstances, including fault conditions and misuse.

Risk identification considers a comprehensive range of causes and consequences and can be performed by subject-matter experts, Stakeholder interviews and Workshops. Risk analysis provides information on action options for decision-making. Modelling and sensitivity analysis can improve appreciation of both likelihood and consequence, before and after risk reduction.

3 **Requirements:** Overall safety requirements are specified in terms of safety functions, other technology and external risk reduction facilities. They are also specified for consideration of all reasonably foreseeable dangerous failure modes, for separation /independence of controls and treatments and for consideration of common cause failures. This step covers the final test of due diligence 'reasonableness'. This is the hard part and requires collective decision-making by Stakeholders.

Risk evaluation considers which risks need treatment and their priority for implementation. Risk treatment collates the agreed options into a plan for implementation. This principle requires that any risk is reduced to a level As Low As Reasonably Practicable (ALARP). If a risk falls between the two extremes of intolerable and broadly acceptable, and the ALARP principle has been applied then the resulting risk is the tolerable risk for that area of concern. The following diagram summarises the level of tolerability regions for each risk level. Risks should be regularly reviewed to ensure that they remain broadly acceptable.

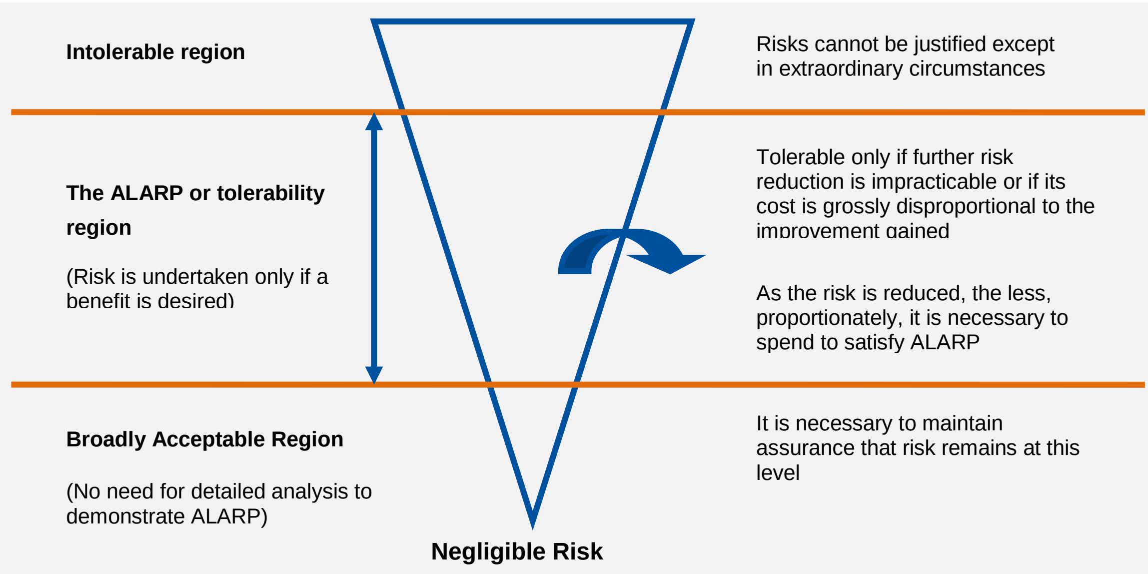


Figure 16: *ALARP Principle*

Selection Of Risk Treatment Options

Selecting the most appropriate risk treatment option involves balancing the costs and efforts of implementation against the benefits derived, with regard to legal, regulatory, and other requirements such as social responsibility and the protection of the natural environment. Decisions should also take into account risks which can warrant risk treatment that is not justifiable on economic grounds, e.g. severe (high negative consequence) but rare (low likelihood) risks.

Risk Assessment Matrix (Ri)

The following 5 x 5 matrix was used to establish the level of risk. Risk can be considered to be the consideration of both Consequence (causation) and Likelihood (probability).

Likelihood \ Consequence	1 (Trivial)	2 (Minor)	3 (Moderate)	4 (Major)	5 (Catastrophic)
A – Almost certain	1A	2A	3A	4A	5A
B – Likely	1B	2B	3B	4B	5B
C – Possible	1C	2C	3C	4C	5C
D – Unlikely	1D	2D	3D	4D	5D
E – Rare	1E	2E	3E	4E	5E

Definitions

Consequence:

5 – Catastrophic:	>10 fatalities, total loss of facilities/services, irreparable heritage/environmental damage (> $10M)
4 – Major:	1 – 10 fatalities, > 50% facilities/services loss, major heritage/environmental damage ($1M – $10M)
3 – Moderate:	Serious injury or illness requiring hospitalisation, 25 – 50% facilities/services loss, moderate heritage/environmental damage ($100K – $1M)
2 – Minor:	Minor injury or illness requiring day patient treatment, 5 – 25% facilities/services loss, minor heritage/environmental damage ($20K – $100K)
1 – Trivial:	Injury or illness requiring first aid treatment, < 5-% facilities/services loss, trivial heritage/environmental damage (< $20K)

Likelihood

A – Almost certain:	Expected to occur in most circumstances
B – Likely:	Probably occur in most circumstances
C – Possible:	Should occur at some time
D – Unlikely:	Could occur at some time
E– Rare:	May occur in exceptional circumstances

Suggested Approval Levels

The following table shows the suggested levels of approval for each of the risk levels identified.

Residual Risk Level	Definition	Acceptability	Suggested Approval Level
4A, 5A, 5B, 5C	Very high risk	Intolerable except in extraordinary circumstances	Minister or Cabinet
2A, 3A, 3B, 3C, 4B, 4C, 4D, 5C, 5D, 5E	High risk	Undesirable, subject to test of gross disproportion	Board, CEO or equivalent
1A, 1B, 1C, 2B, 2C, 2D, 3D, 3E, 4E	Moderate risk	Tolerable, subject to ALARP risk reduction	Divisional Management
1D, 1E, 2E	Low risk	Broadly acceptable	Project Management

Hyder Consulting Pty Limited
ABN 76 104 485 289
Level 16, 31 Queen Street
Melbourne Vic 3000
T: +613 8623 4000
F: +613 8623 4111

www.hyderconsulting.com