Trolley Bus Operation of Bus Rapid Transit

WELLINGTON CABLE CAR LTD.

Report

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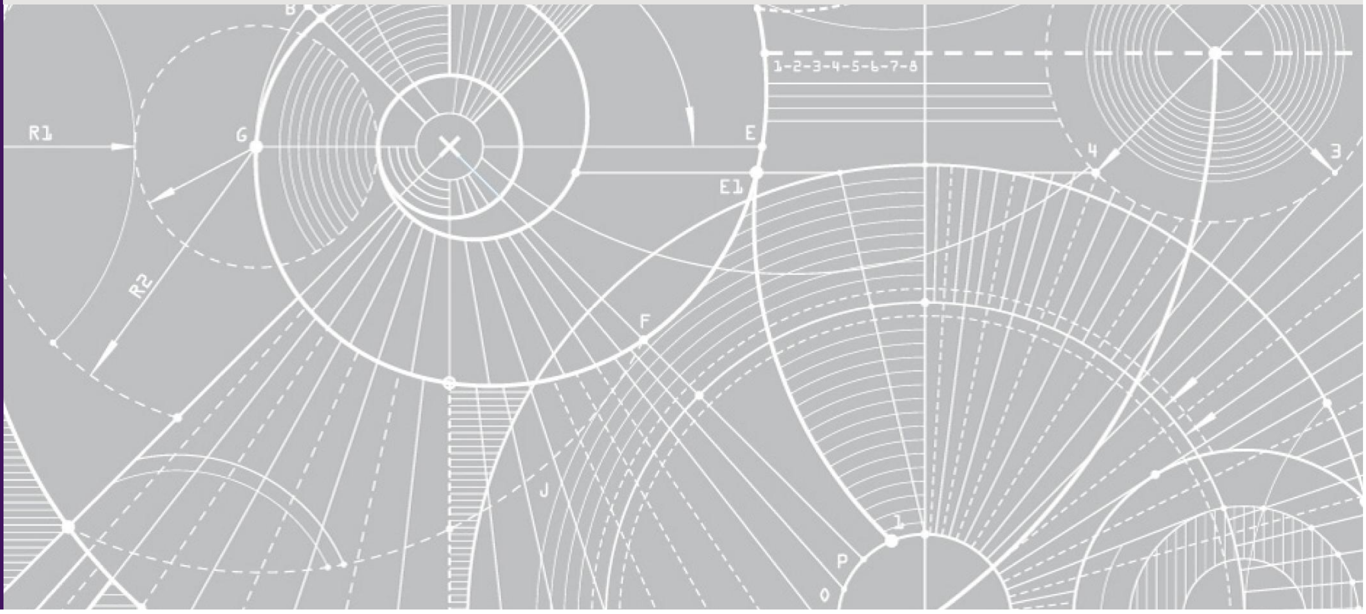

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SKM

Trolley Bus Operation of Bus Rapid Transit

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Contents

Important note about your report

The sole purpose of this report and the associated services performed by Sinclair Knight Merz ("SKM") is to assess the operation of Trolley Bus services on the proposed Wellington Bus Rapid Transit Spine in accordance with the scope of services set out in the contract between SKM and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, SKM has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, SKM has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

SKM derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. SKM has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by SKM for use of any part of this report in any other context.

It should be noted that this assessment is a desk top study drawn from a literature search and web based analysis of Trolley bus operations elsewhere.

This report has been prepared on behalf of, and for the exclusive use of, SKM's Client, and is subject to, and issued in accordance with, the provisions of the contract between SKM and the Client. SKM accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party

Executive Summary

Sinclair Knight Merz was commissioned by Wellington Cable Car Company to assess the potential for trolley bus operation of the proposed Wellington Bus Rapid Transit system. There are two components to the analysis:

1) An initial assessment of the BRT scheme to determine whether there were any features of the BRT proposal which would render trolley buses as being fundamentally incompatible with BRT as proposed for Wellington, and
2) An investigation of the relative operational issues, capital and operating costs, maintenance costs and environmental factors to make a comparison between the potential BRT modes.

The Bus Rapid Transit Proposal

The BRT option developed by AECOM provides for new high capacity and high quality buses running on dedicated bus lanes with priority at signals. From Wellington Railway Station, the BRT route follows the Golden Mile to the end of Courtenay Place, then via Kent/Cambridge Terraces to the Basin Reserve where the line splits with braches to Kilbirnie and Newtown (see map at **Figure 1**).

Overhead trolley bus catenary is already available over most of the BRT route. The AECOM analysis allowed for diesel or trolley bus operation. It would appear that there are no attributes in the BRT system as proposed for Wellington which would preclude the use of trolley buses.

Trolley Bus Operations on BRT Systems

Trolley bus operated BRT systems can be found in Ecuador, Venezuela, and Iran. A trolley bus operated system is also proposed for a Leeds BRT system in the UK. There are trolley bus systems elsewhere in the world, including trolley bus operation over sections of segregated busway. Wellington is probably the only example remaining of a trolley bus system in a country where driving is on the left. The small market size means that right hand drive trolley buses will be expensive compared with left hand drive vehicles.

Capital Cost

Based on the international experience, an articulated trolley bus for the BRT proposal is likely to cost approximately $1million per vehicle – about $300,000 dearer than the cost of a new diesel bus as assumed by AECOM. However, a standard diesel bus averages 18 years' in service while a trolley bus averages 24 years.

Trolley bus catenary is already in place over most of the BRT route. An estimated 2 km of new overhead wiring would be needed, at a cost including power supply infrastructure of approximately $1.5 million.

Operating Costs

The cost of diesel fuel/power supply is the main differential between the diesel and trolley bus service delivery cost. The cost of power for trolley bus operation is currently about two thirds of the cost of diesel fuel to deliver the same level of service. At current fuel prices, the fuel cost for trolley bus operation would be $260,000 per year lower than for diesel bus operation. By 2025 trolley bus fuel costs would be half of the diesel fuel costs, $570,000 per year lower (at current price levels).

For buses operating under the same conditions, vehicle maintenance costs for trolley buses are likely to be no higher and possibly lower than the cost for equivalent diesel buses. The main difference between trolley and diesel bus operation is the need to maintain the overhead catenary. An extra 2 kilometres of trolley bus overhead equipment would need to be provided given that most of the BRT route is already "under wire" and, at current price levels, this would imply an additional $74,000 pa for catenary maintenance.

Overall Differential

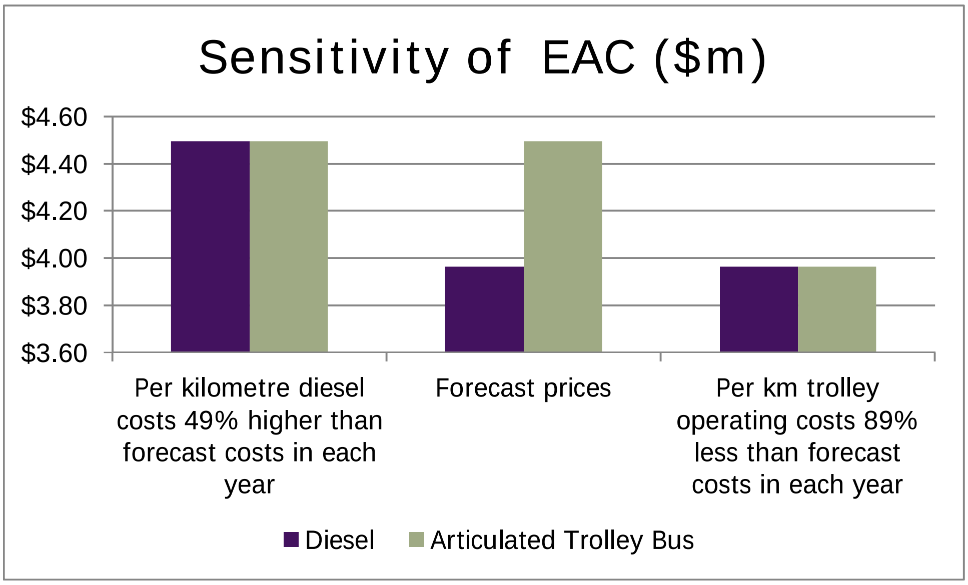
The estimated Equivalent Annual Annuity Cost (EAC) of the BRT operation (40 bus fleet) has been estimated, for a 30 year project life, as follows:

Diesel bus operation $4.0 million

Trolley bus operation $4.5 million

A sensitivity test was undertaken to determine the fuel price differential which would give equal EAC values (see graph below). The output suggests that diesel running costs per km would need to be 49% higher or electricity running costs per km to be 89% lower. This indicates that the model's conclusions are not particularly sensitive to fuel prices and it is the capital cost of the buses that is driving the difference in annualised costs.

Figure E1: Fuel cost sensitivity



Source – SKM Analysis based on 30 year project life

Service delivery

Modern trolley buses and diesel buses have similar performance profiles. Passenger capacity is virtually identical. Trolley buses have better uphill acceleration when fully loaded but there is a perception that trolley buses are subject to failures or breaks in the overhead catenary. (In reality, modern trolley buses have ancillary batteries allowing them to bypass most power supply interruptions.)

Unlike diesel buses, trolley buses have minimal noise and no particulate emissions on the road. The presence of overhead wiring would add to the sense of permanence and route presence provided by the BRT giving potential passengers more confidence in the operation.

1. Introduction

1.1 Background

Greater Wellington Regional Council has received a report following an analysis of the options for the development of the public transport spine between Kilbirnie/Newtown and Wellington Railway Station[1]. The Kilbirnie and Newtown branches combine to follow a common route between the Basin Reserve and the station which includes the "Golden Mile" – a busy bus corridor through the city centre. The options assessed were:

- Enhanced bus priority to benefit existing bus routes
- Bus Rapid Transit (BRT)
- Light Rail Transit

The findings of this options' study include the outcome that the Bus Rapid Transit system provides the highest benefit cost ratio (BCR).

Public transport usage in the Wellington Region (73.4 trips/per person annually) is considerably higher than in Auckland (45.2) and Christchurch (23.4)[2]. Public transport usage is also on a growing trend from a low of 23 million trips in 1993 to over 35 million trips in 2011-12. Two thirds of all public transport trips are made by bus. There are 470 buses in the fleet, of which 60 are trolley buses. The trolley bus fleet was significantly upgraded in 2007 to 2009. The trolley bus overhead equipment is owned and maintained by the Wellington Cable Car Company Ltd.

1.2 This Study

Wellington Cable Car has commissioned this study to assess the potential for trolley bus operation of the Bus Rapid Transit system. Most of the proposed route is already under trolley bus wire. The most notable exception is the section of State highway 1 from the Basin Reserve through to the Troy Street roundabout. Although electric traction is not ruled out, the AECOM report does not specifically address the issue of trolley bus operation but the analysis is clearly based on diesel bus operation. With the BRT in place, the expectation is that most other buses operating through the city centre would be removed from the "Golden Mile" and follow parallel routes. Given the current intensive use of this corridor by trolley buses, Wellington Cable Car is keen to consider the comparative merits of trolley- and diesel-bus operation on the BRT.

The study is in two parts:

3) An initial assessment of the BRT scheme to determine whether there were any features of the BRT proposal which would render trolley buses as being fundamentally incompatible with BRT as proposed for Wellington, and
4) An investigation of the relative operational issues, capital and operating costs, maintenance costs and environmental factors to make a comparison between the potential BRT modes. The principal features to be addressed are:
    a) Cost
    b) Speed
    c) Capacity
    d) Other factors (environmental, permanency benefits and service quality) will also be addressed

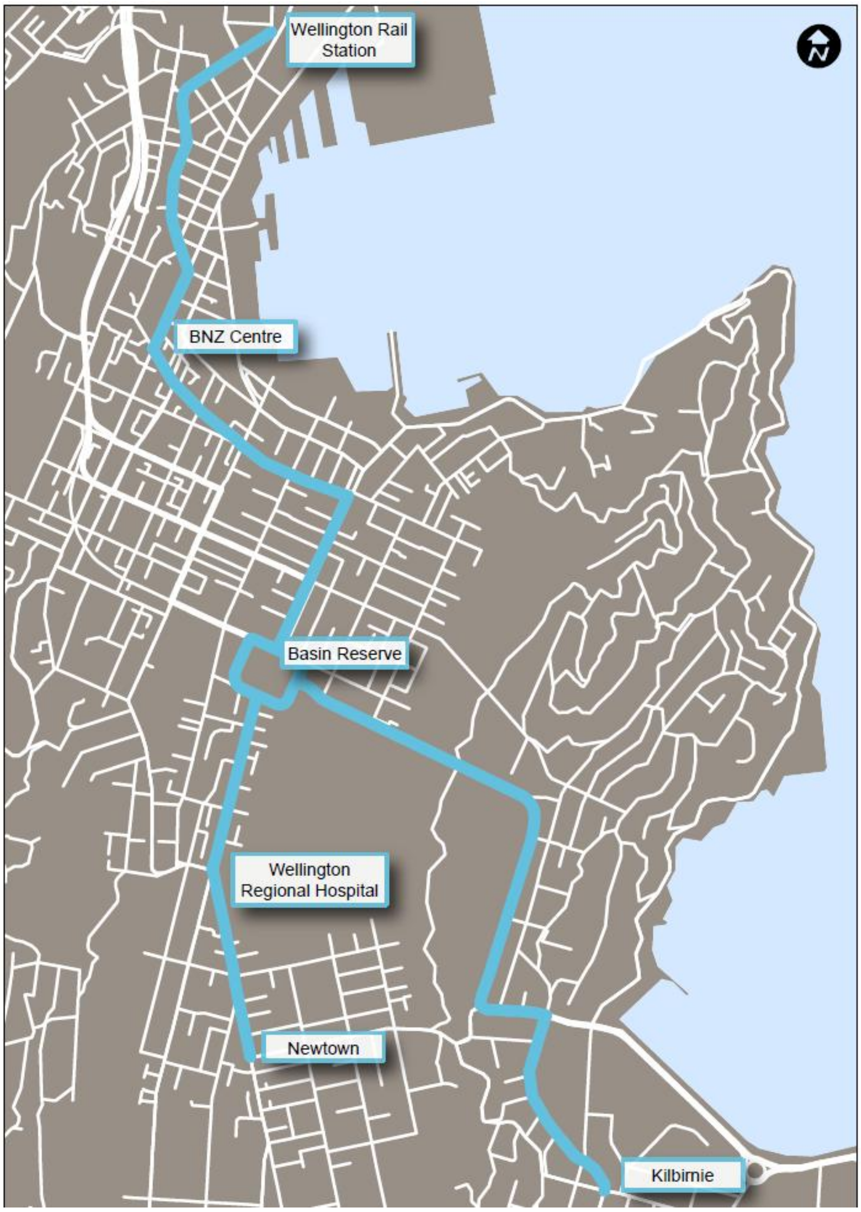
[1] Wellington Public Transport Spine Study, Summary of Key Findings, AECOM for Greater Wellington Regional Council, 2013
[2] Wellington Regional public Transport Plan 2011 - 2021

2. The Bus Rapid Transit Proposal

2.1 Description

Figure 1 below shows the proposed BRT network.

Figure 1: Proposed BRT network for the Wellington Public Transport Spine[3]



Summarising the description in the AECOM report, the BRT option provides new high capacity and high quality buses running on dedicated bus lanes with priority at signals. The AECOM analysis indicates that the BRT buses could be electric vehicles (using underground induction or overhead wires) or hybrid or diesel vehicles. The BRT has nine kilometres of dedicated route. From the Wellington Railway Station, the BRT option follows the Golden Mile to the end of Courtenay Place. On Kent/Cambridge Terraces BRT would travel alongside the central median to the Basin Reserve. From the Basin Reserve to Newtown, BRT would continue to travel down

[3] Wellington Public Transport Spine Study, Summary of Key Findings, AECOM for Greater Wellington Regional Council, 2013

the centre of the road. To Kilbirnie BRT would use the State Highway corridor through the duplicated Mount Victoria tunnel and along the widened Ruahine Street and Wellington Road.

Apart from the section of State highway 1 from the Basin Reserve through to the Troy Street roundabout, existing trolley bus wiring is provided throughout the proposed BRT route.

The BRT would operate as two routes running a peak hour headway of every four minutes on the Newtown and Kilbirnie branches and combining to form a two minute headway between the Basin Reserve and Wellington station. A fleet of 40 buses is required to operate the service. An attractive feature of the BRT operation (compared with light rail) is the ability to operate through services to and from places beyond the southern termini of the BRT. This would reduce the need for feeder services and passengers to interchange. With overhead wiring already in place, this flexibilty would be available for both diesel and trolley bus BRT operation. However, the analysis undertaken in the AECOM study is based on the BRT services provided between Newtown/Kilbirnie and Wellington Station only.

2.2 Suitability for Trolley Bus Operation

The BRT option assessed in the AECOM analysis allowed for articulated or double decker high capacity vehicles. Trolley buses can be manufactured in articulated format and, historically, double deck trolley buses have been operated in many cities. It would appear that there are no attributes in the BRT system as proposed for Wellington which would preclude the use of trolley buses.

3. Trolley Bus Operations on BRT Systems

3.1 International Experience[4]

Although, internationally, most Bus Rapid Transit systems use diesel buses there are some notable examples of trolley bus operated BRT networks.

Quito, Ecuador

The Quito trolley-bus operated BRT line was opened in 1995. It is part of a wider BRT network but other routes are operated by diesel buses. The trolley bus BRT route is 18.7 kilometres in length. 113 articulated trolley buses are used on this BRT line with headways as low as 60 seconds at peak periods. The main reason for adopting trolley bus operation was the high level of pollution caused by numerous diesel buses passing through the historic city centre. It was part of a wider plan to remove hundreds of bus services from the city centre to new intermodal terminals away from the CBD.

Mérida, Venezuela

The first stage of the Mérida electrified BRT system, a 10 kilometre line south of the CBD, was opened in 2007. The system is modelled on the Quito BRT system and has similar objectives – to address the congestion and environmental issues caused by the high volumes of petrol, gas and diesel powered vehicles in the narrow valley at high altitude (1,500 metres). 45 articulated trolley buses with auxiliary diesel motors are used on the BRT system currently operating.

A similar trolley bus operated BRT system is under construction in the city of Barquisimeto, Venezuela.

Tehran, Iran

Two bus routes operating to the north east of the city operate almost entirely in a 6.9 kilometre segregated busway located in the middle of a wide road. This effectively makes the service a BRT system although not marketed as such. Trolley bus operation in Tehran commenced in 1992.

There are three other trolley bus routes in the city operating in mixed traffic, not dedicated busways, and a fleet of 65 articulated trolley buses is deployed for the whole network. However, the busway trolley buses are based in one depot and the conventional trolley bus routes are based in another depot.

Leeds, UK[5]

A 14km trolley bus-based rapid transit scheme is proposed to link Stourton to the south of Leeds with Holt Park in the north west of the city, via Leeds City Centre. Although the system is still in the development stage, it is referred to here because of the similarities between the deregulated public transport service delivery environments in the UK and New Zealand. The proposed Leeds BRT system will provide a core frequency of 10 buses per hour on both the northern and southern routes, overlapping in the city centre. A peak vehicle requirement of 19 buses will be needed to operate this service, suggesting a total fleet to allow for operational spares of at least 21 vehicles.

The Business Case Submission explains the reason for the choice of trolley buses. The proposal is being developed under the provisions of the UK's Transport and Works Act (TWA) which is only available for guided bus-based projects and only then for the guided section and associated ancillary works. If the technology did not use a specialist trolley bus fleet then access would be open to all diesel bus operators and the maximum degree of possible system segregation (and hence also the maximum degree to which the system could be guided) is unlikely to be sufficient to warrant a whole system TWA order. The promoters of the BRT would not

[4] This information comes from internet research
[5] Leeds Busway Business Case Submission, March 2012

be able to set a quality threshold for the services provided using conventional or hybrid buses since this would be a disproportionate barrier to entry into the market for new operators.

Other Trolley Bus Systems

There are trolley bus systems elsewhere in the world, including trolley bus operation over sections of segregated busway. Wellington is probably the only example remaining of a trolley bus system in a country where driving is on the left – at least until the Leeds BRT is implemented (planned for 2018 but subject to further approval stages). Trolley bus suppliers are geared for the production of trolley buses with passenger doors on the right. The comparatively very low demand for trolley buses with left side passenger doors (and right hand drive equipment) has an implication for the cost of new trolley buses (see below).

4. Cost

4.1 Capital Cost - vehicles

Trolley buses are unique public transport vehicles for which the market is relatively small outside of Europe, North and South America. The manufacturing costs are higher than for diesel buses. There are very few, if any, purchasers of right hand drive trolley buses as would be required for Wellington. There is not a big market for manufacturers with few economies of scale available to provide discounted prices to purchasers of new right hand drive trolley buses.

Various analyses have pointed to a purchase price differential for trolley buses from 50% to 100% when compared with an equivalent diesel bus.

- A study for King County (Seattle) USA compared the cost of replacing the ageing trolley bus fleet of 159 vehicles. The capital cost of a new trolley bus was found to be 64% more expensive than an equivalent diesel hybrid bus[6].
- An analysis undertaken for Salzburg, Austria, in March 2004 found trolley bus prices to be about twice the price of an equivalent diesel bus[7].
- An analysis by the UK based Trolley Bus Group found trolley bus prices to be €100k to €400k dearer than equivalent diesel buses, depending on the size of the order and the specification of the diesel bus[8]. These differences appear to be consistent with the 50% to 100% differential in the USA and Salzburg examples.
- Separate data for Arnhem (Holland) and Denmark, reported in 2000, indicate a price differential of 100%[9].
- A Canadian study puts the trolley bus cost at 100% higher than the cost of a diesel bus and 50% higher than the cost of a hybrid diesel/electric bus[10].

When comparing the capital cost of trolley buses, the expected life of the vehicle needs to be considered. Trolley buses typically have an operational life of three to six years longer than equivalent diesel buses[11]. This reflects a 30% to 50% longer operational life. This outcome is derived from an analysis of existing trolley bus systems and it needs to be noted that in cities where diesel and trolley buses are operated, trolley bus operations are usually on the more intensive, high frequency, inner city routes. These routes would normally be in areas of higher density population and have well used, more closely spaced, bus stops. This is because the power supply infrastructure can only be fully justified where transit demand is high. The comparison is therefore likely to be between high mileage trolley buses and lower mileage diesel buses. In a true "like for like" comparison of trolley buses and diesel buses delivering exactly the same service levels it might be expected that trolley bus life will be at least 50% longer than the equivalent diesel buses. This will be reflected in the comparative lifetime costs for diesel powered and trolley buses (see table 4.1 below).

A further consideration is the second hand value of the vehicles at the end of their working life. Diesel buses can often be on-sold for further work. However, there does not seem to be any significant prospect of anything other than scrap value for second hand, right hand drive, trolley buses unless there is a revival in this mode of urban public transport.

A standard diesel bus currently costs about $400,000 to purchase. The assumed cost of a diesel powered articulated bus is for the AECOM analysis is $700,000. Based on the international experience discussed above, an articulated trolley bus for the BRT proposal is likely to cost $900,000 to $1.2million per vehicle. However, trolley buses typically have a longer working life. This analysis assumes a cost of $1 million for a new articulated

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[6] Trolley Bus System Evaluation, King County Metro, April 2011
[7] Position Paper Trolley bus, Dr Heinz Schaden (Mayor) and Gunter Mackinger (General Manager), Salzburg, Austria, March 2004
[8] http://www.tbus.org.uk/article.htm
[9] New Concepts for Trolley Buses in Sweden, ScanTech Development AB, 2000
[10] Hybrid Diesel-Electric Bus / Trolley Bus Demonstration Project: Technical Comparison of In-Use Performance, Dr. David Checkel Mechanical Engineering, University of Alberta April 18, 2008
[11] Development of Trolley bus Passenger Transport Subsystems in Terms of Sustainable Development and Quality of Life in Cities, International Journal for Traffic and Transport Engineering, 2011, 1(4): 196 – 205

trolley bus. A standard diesel bus typically averages 18 years' in service while a trolley bus life averages 24 years.

Table 4.1 below shows the calculation of the annualisation of the diesel and trolley bus costs for the BRT.

Table 4:1: Annualisation Cost for Diesel and Trolley Bus Operations on BRT

	Articulated Diesel Bus	Articulated Trolley Bus
Purchase Price per bus (2012 prices)	$700,000	$1 million
Buses required (AECOM data)	40	40
Total Purchase Price	$28 million	$40 million
Payment period (operating life of bus)	18 years	24 years
Residual (resale) value	$35,000	$10,000
Interest rate	7.5%pa	7.5%pa
Annual payments for 40 bus fleet (2012 prices)	**$2.92 million**	**$3.64 million**

4.2 Capital cost – infrastructure

The most significant difference between diesel and trolley bus operation is the requirement for an electrical power supply system, overhead wiring along the route to be followed. For the Wellington BRT proposal, most of the trolley bus infrastructure is already in situ although some sections are worn and will need replacing in the near future. This replacement would be needed whether or not the BRT system is introduced if trolley buses are to be retained for non-BRT routes. Trolley bus power supply infrastructure would need to be provided through the new BRT tunnel.

A 2011 study in the European environment puts the trolley bus infrastructure component at €210,000 per kilometre for the overhead wiring plus the cost of supporting columns, power supply connections and junctions – probably less than €500,000 per kilometre overall[12]. The Wellington Public Transport Spine Study estimates a capital cost of $207 million for the 9.5 km busway, equivalent to $22 million per kilometre. This figure will include the cost of the (diesel powered) vehicles. The cost of the overhead power supply infrastructure required for trolley bus operation is not included in the cost but, as noted above, the infrastructure is already in place for all but a short section of the proposed BRT route. It may also be necessary to relocate the overhead from the kerbside to centre lanes along some sections of route. For this analysis it has been assumed that an extra two kilometres of trolley bus wiring would be required for the BRT system at an estimated cost of $1.5 million.

There may be a need to add substations to boost the power supply if the power demand for BRT trolley bus operated services is significantly higher than the existing power demand over these route sections.

[12] Development of Trolley bus Passenger Transport Subsystems in Terms of Sustainable Development and Quality of Life in Cities, International Journal for Traffic and Transport Engineering, 2011, 1(4): 196 – 205

4.3 Operating cost

Apart from maintenance costs, see below, the cost of diesel fuel/power supply is the main differential between the diesel and trolley bus service delivery cost. We have assumed that the drivers are drawn from the same pool of employees with equivalent skill levels for diesel and trolley bus driving and are paid at the same rate regardless of the specific power system.

The cost of diesel is determined by international market conditions and also the strength of the NZ dollar against the US dollar, the currency currently used for the oil trade. Companies with high volumes of fuel usage can often negotiate term contracts at favourable rates with supply companies. In the longer term, the price of diesel fuel is expected to rise due to increasing demand, especially from the developing world, and constrained supply.

The price of electricity for trolley bus operation is determined by the nature of the power supply. If power is generated using local renewable resources, such as hydro electricity and geo-thermal (as is the case for a significant proportion of the New Zealand electricity supply), the power supply cost is likely to be more stable than in countries where electricity generation is dependent on fossil fuels such as coal or oil.

Detailed operating costs for diesel powered and trolley buses in Wellington have not been provided. NZTA Research Report RR472[13] provides a base fuel cost estimate for a standard diesel bus of 36.9 cents per bus kilometre in 2009-10. At 2012 price levels (the latest available price data) this figure had increased marginally to 37.6 cents per kilometre, excluding GST. This is the fuel price assumed to have been used in the AECOM analysis for the BRT.

For a standard trolley bus, fuel consumption is generally quoted to be in the range 190 to 250 kWh per 100km. Clearly this will vary with the local operating conditions, topography, vehicle specification and on-board facilities such as air conditioning and heating. At 2012 electricity supply price levels (obtained from the Ministry of Economic Development web site) and assuming fuel consumption at 220 kWh per 100km, power supply for a standard trolley bus is estimated to cost 24.3 cents per bus kilometre, including GST, at 2012 price levels.

The cost of power for trolley bus operation is therefore estimated to be approximately two thirds of the cost of diesel buses to deliver the same level of service. The Ministry of Economic Development Energy Price Forecasts suggest that diesel prices will rise faster than electricity prices over the medium to long term in New Zealand. By 2025, the fuel cost per kilometre for a trolley bus operation will be 51% of the equivalent cost for diesel bus operation. Table 4.2 below shows the 2012 and 2025 fuel cost savings (at 2012 price levels) for the BRT service as specified.

Table 4.2: Annual Fuel Cost for diesel- and trolley-bus operation of BRT services

		Energy Cost 2012			Energy Cost 2025		
	BRT Annual Bus Kilometres (‘000)	Standard bus ($ per km)	Articulated bus ($ per km)	Annual Fuel/power cost ($million)	Standard bus ($ per km)	Articulated bus ($ per km)	Annual Fuel/power cost ($million)
Diesel	1,587.2	$0.38	$0.47	$0.74	$0.60	$0.74	$1.18
Trolley bus	1,587.2	$0.24	$0.30	$0.48	$0.31	$0.38	$0.67
Difference				$0.26			$0.57

[13] New Zealand Bus Policy Model, February 2012, NZ Transport Agency, research report 472, Appendix D

Sources: BRT bus kilometres, AECOM data. Energy cost (2012 and 2025) Ministry of Economic Development data. Energy consumption data for both standard and articulated buses derived from SKM literature search.

There are some other operating cost savings associated with trolley bus operation. Trolley buses do not need to be fuelled at the start of each operating day and the lower weight of trolley buses (because of the absence of an on board fuel supply) has less of an impact on the road surface. These savings are relatively small and have not been included in the calculation above.

Overall, annual operating costs will be $260,000 per annum lower at 2012 energy price levels rising to $570,000 per annum lower by 2025 (at constant price levels).

4.4 Maintenance cost – vehicles

Comparisons between the maintenance costs for diesel buses and trolley buses tend to conclude that the direct vehicle maintenance costs (ie excluding catenary maintenance) are broadly similar[14][15]. For the proposed Leeds NGT (New Generation Transport) BRT proposal, the proponents state that *"the cost of maintaining a modern trolley bus is generally lower than for a diesel equivalent bus, even when considering the maintenance cost of overhead wiring and substations"* [16]. A number of analyses have indicated higher trolley bus than diesel bus maintenance costs, but these typically refer to the maintenance of existing, aged trolley buses in a given fleet and not a direct like for like comparison. From these comparisons it is reasonable to conclude that the direct vehicle maintenance costs are unlikely to exceed those of equivalent diesel buses operating a similar schedule.

4.5 Maintenance cost – catenary

Maintenance of the overhead wiring is a cost unique to trolley bus operations. The current annual cost of maintaining the Wellington trolley bus network overhead is $3 million per annum[17]. This cost is for the 81 track kilometres on the existing network and is equivalent to $37,000 per track kilometre per year.

The proposed BRT system is 9.5 kilometres in length, giving 19 track kilometres of overhead wiring if trolley bus operation is adopted. Some additional overhead wiring will be required between the depot and the BRT, but these operations are likely to be under the wires already in place. The BRT costs should include a component for maintenance of the access track kilometres so this analysis is based on a total of 20 track kilometres attributed to the BRT operation. There may be some residual non-BRT trolley bus operation using the BRT network, especially through Wellington CBD. These operations might be expected to contribute to the cost of maintaining the overhead catenary.

On this basis the additional annual cost of maintaining the overhead catenary if the BRT was operated with trolley buses would be 2 x $37,000 = $74,000 per annum.

4.6 Cost of BRT operation by Trolley Buses - Summary

The table below provides a comparison of the annual cost of BRT operations by diesel buses and trolley buses.

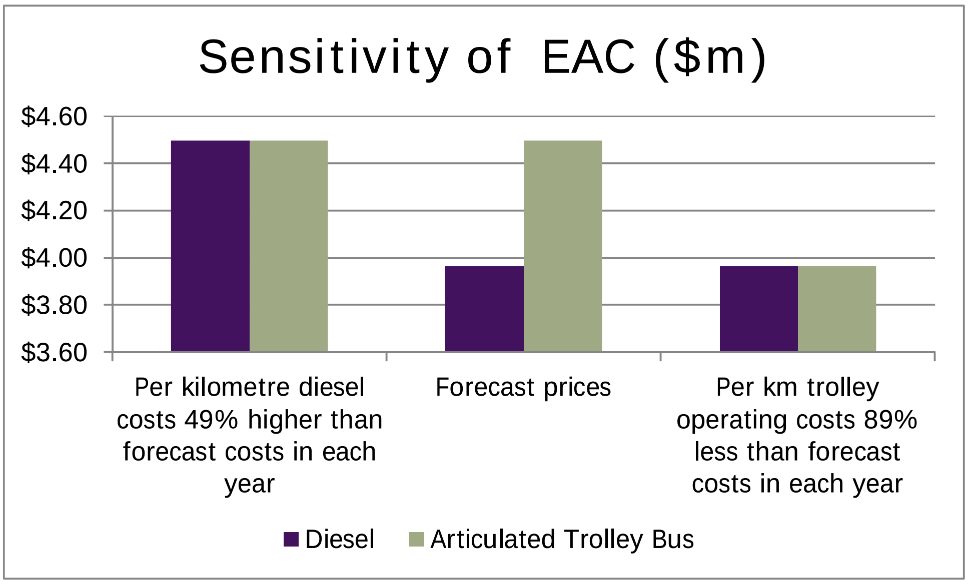
[14] See http://www.eltis.org/index.php?id=13&study_id=3334
[15] Alternative Scenarios for Trolley Bus Replacement Cost and Environmental Implications, Booz Allen Hamilton, Edmonton, Canada, 2008
[16] Leeds NGT – Major Scheme Business Case, October 2009
[17] Figure provided by Wellington Cable Car Company. NZTA Research Report RR472 gives a figure of $4.5 million per annum. The analysis in this document is based on the $3 million per annum figure

Table 4.3: Comparative cost of BRT operations

	Diesel bus operation	Trolley bus operation
Initial Capital cost - buses	$28.42 million *(replaced at 18 years)*	$40.60 million *(replaced at 24 years)*
Capital cost – Trolley bus infrastructure	Nil	$1.50 million
NPV (30 year project life)	$48.9 million	$57.4 million
Equivalent Annual Annuity (EAC)	$4.0 million	$4.5 million
EAC difference *(Trolley bus less diesel bus costs)*		**+ $0.5 million**

It should be noted that the forecast is for diesel fuel costs to grow at a faster rate than electricity supply costs. By 2025, trolley bus energy costs will be $570,000 per year lower than diesel bus energy costs (in $'2012). The difference between trolley bus and diesel bus costs will therefore decline over time. A sensitivity test was undertaken to determine the fuel price differential which would give equal EAC values. The output suggests that diesel running costs per km would need to be 49% higher or electricity running costs per km to be 89% lower. This is shown in the bar graph below. This indicates that the models conclusions are not particularly sensitive to the fuel prices and it is the capital cost of the buses that is driving the difference in annualised costs.

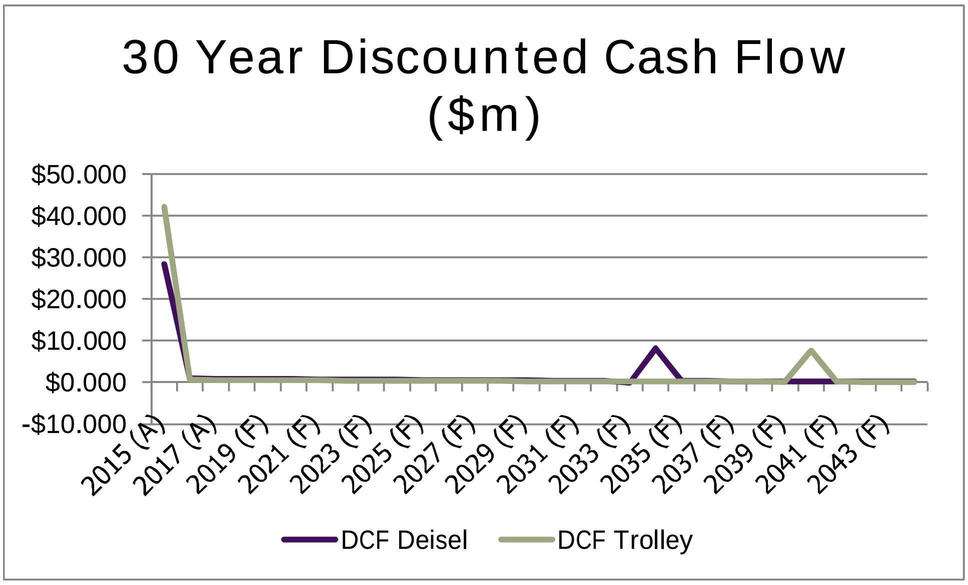
Figure 2: Fuel cost sensitivity



Source – SKM Analysis based on 30 year project life

The figure below shows the 30 year Discounted Cash Flow graph for diesel and trolley bus operation of BRT services. Note that there is no revenue included in this analysis and a discount rate of 7.5%pa is applied. It has also been assumed that bus prices will rise 0.5%pa in real terms. The end of life resale value of diesel buses is assumed to be 5% of the initial purchase price while trolley buses, with fewer potential buyers are expected to be worth just 1% (scrap value) of the purchase price.

Figure 3: Discounted cash flow for diesel and trolley bus operation of BRT



5. Service Delivery

5.1 System capacity

Modern trolley buses and equivalent diesel buses have virtually identical passenger carrying capacity.

5.2 Vehicle performance

Modern trolley buses, with well-maintained overhead equipment, and diesel buses can deliver virtually the same operational speeds in service. Operational comparisons in cities with both diesel and trolley bus services often indicate diesel buses delivering higher in service speeds than trolley buses. However, in these cities, trolley buses operate on the routes with more frequent bus stops and higher patronage levels (thus justifying the infrastructure investment in the power supply system) and the comparison is therefore not made on a common basis.

Trolley buses do have better acceleration profiles than diesel buses, especially on inclines and with full passenger loads. It should also be noted that diesel buses are also carrying the weight of their fuel supply which will have an impact on acceleration, especially at the start of the operating day.

Reliability is sometimes considered to be an issue when comparing diesel powered and trolley bus operations. However, many of these comparisons involve newer diesel buses and trolley buses in the same fleet which are approaching the end of their operational life. We are not aware of any evidence of a difference in reliability between diesel and trolley buses of the same age.

Power supply interruptions can affect trolley bus operations more than diesel buses. However, modern trolley buses are equipped with ancillary batteries to allow them to operate over some distance without access to the overhead catenary. Trolley buses therefore have similar operational flexibility to diesel buses when faced with on-road obstructions although this is limited by the range of the back-up battery.

5.3 Environmental Impacts

The environmental benefits of trolley bus operations have been widely considered in numerous studies in New Zealand and overseas. At the point of service delivery trolley buses produce no fumes or exhaust emissions. However, because most of New Zealand’s electricity generation does not come from carbon emitting production there are also few remote carbon emissions.

Trolley buses are considerably quieter than equivalent diesel buses. This has considerable benefits for passengers on the bus and for the environment in the streets along which trolley buses operate. There is a potential safety issue for pedestrians who try to cross the road in front of a bus they did not hear. However, trolley buses have been operating in Wellington for over sixty years and most pedestrians will be aware of their presence.

The visual impact of the overhead wiring is often mentioned as a disbenefit of trolley bus operation. However, given the wiring has already been in place for many years in Wellington it will be less of an issue for the BRT system than if a new trolley bus system was being considered. A positive impact of the overhead wiring is that it gives a sense of permanency to the public transport route. This will be enhanced by the surface infrastructure associated with the BRT, increasing the attractiveness of the proposed service to potential passengers.