Auckland Transport

Auckland light rail peer review - Part C: Cost estimates (Draft 2)

26 July 2015

N207/Rep/1552

STRICTLY CONFIDENTIAL

Ian Wallis Associates Ltd

ian@ianwallis.org

Contents

EXECUTIVE SUMMARY

1. Scope

This is one of three papers prepared for Auckland Transport by consultants Ian Wallis Associates (IWA), as the outputs of a (limited) peer review of AT's proposals for a light rail network for Auckland.

This paper reviews the cost estimates prepared by the AT project team, and specifically:

> *"Whether the estimates of incremental public transport capital costs (infrastructure and vehicles) and operating costs, relative to the bus-based base case, are sufficiently robust for this stage of option assessment".*

This paper reviews the cost estimates prepared by the AT project team for the LRT option and the alternative bus option, under three main cost groups: operating costs, vehicle capital costs, and infrastructure capital costs. For each of these groupings, the review examined whether the project team cost estimates are sufficiently robust at this stage of the project assessment, mainly by comparing these estimates against cost data for LRT schemes in Australia. Where the cost estimates appear inconsistent with this evidence, it provides estimates, at an indicative level, that appear more appropriate.

2. Project team cost estimates

The project team best estimate costs for the LRT scheme were (NZ$2014):

- Infrastructure capital costs: $2606 M
- Annual operating costs (including vehicle capital charges): $36 Mpa, compared to equivalent operating costs for a bus option of $67 Mpa.

3. Peer review assessment

For **infrastructure capital costs,** we consider that the project team estimate ($2606 M) is broadly consistent with infrastructure costs involved in recent LRT schemes (now operational or in the planning/procurement stage) in Australia, after allowing for the characteristics of the proposed Auckland scheme.

For **operating (including vehicle capital) costs**, we consider that:

- The LRT operating costs are very considerably under-estimated.
- The LRT vehicle capital costs are largely consistent with other evidence sources, but their conversion into equivalent annual capital charges is not consistent with normal practice for such schemes.
- The bus operating costs and vehicle capital charges are broadly consistent with our own estimates.

Based on these findings, our best estimates (aside from the infrastructure capital costs), are that:

- The LRT option costs would be about $116 Mpa (including $16 Mpa for feeder buses in the corridor) compared with the project team estimate of $36 Mpa (excluding any feeder buses).
- The comparable bus option costs would be about $86 Mpa compared with the project team estimates of $67 Mpa.

The table sets following out the main components of the project team's costing analyses and our assessment of these, that together result in the above summary findings.

TABLE: SUMMARY OF COSTING FINDINGS

Aspect	Project team assessment	Peer review comments and assessment
A. VEHICLE TYPES AND CAPACITIES		
1. LRT vehicles	• Dimensions: length 45m (7 modules, 100% low floor). • Capacity: planning standard 300 passengers/vehicle (based on full seated load plus 4 standees/m^2 of available floor area).	• Dimensions: agree, reasonable assumption for planning purposes at this stage of project. • Capacity: standard of 4 standees/m^2 not reasonable as peak hour average (although may be obtainable on individual trips). Based primarily on Melbourne tram/LRV standards (and also having regard to AKL & WGN metro-rail standards), propose planning standard of 2.9 standees /m^2, resulting in total vehicle planning capacity of 240 passengers /vehicle (ie 20% below project team figure).
2. Bus vehicles	• For main analyses, assumed 'standard' size buses in corridors affected, with c. 37 seats and effective planning capacity of 50 passengers, ie similar to majority of current AKL fleet. Also assumed larger single-deck buses (as now) on busway services. Also considered double-decker buses, with up to 90 seats and effective planning capacity of c. 100 passengers (did not use these in costing analyses).	• Accepted project team assumptions on bus types and capacities as reasonable at this stage of project. However, have undertaken main cost assessments based on both single-decker (50 passenger capacity) and double-decker (100 passenger capacity) vehicles.
B. VEHICLE CAPITAL COSTS		
1. LRT vehicles	• Two sets of estimates were made based on the above vehicle type, in both cases relating to wire-free technology (ie battery-based, with recharging arrangements yet to be determined): WT Partnership estimate $6.13M, Turner & Townsend $6.80M. This latter figure was used in the costing assessment. • The cost assessment also assumed a 30 year vehicle life, and vehicle 'renewal' after 15 years (at 20% of initial cost). The annual capital charge per vehicle was based on straight-line (historic cost) depreciation over the vehicle life.	• From review of recent information (mainly in Australia) on LRV costs, and allowing for wire-free technology, our best estimate of costs was about 10% below the project team $6.80M (for convenience we used the $6.13M figure). • Accepted the project team assumptions on vehicle life and mid-life renewal. • Annual vehicle capital charge was estimated on an annuity basis over the vehicle life, using a 7.5%pa real interest rate (such an approach is much more consistent with a finance lease arrangement, or PPP arrangements, than the historic cost depreciation approach). The result is for an annual capital charge per vehicle about twice the project team figure ($530 kpa/vehicle as against $270 kpa).
2. Bus vehicles	• For main analyses, assumed 'standard' bus cost of $500k, 12 year life, and half-life renewal (at 20% of initial cost). For double-decker buses, assumed costs would be 30% higher (although these figures were not used in the costing analyses). • As for LRV, annual capital charges based on historic cost depreciation.	• Estimated 'standard' bus cost of $440k (12% lower than project team) and for double-decker same cost as project team. In both cases, assumed 20 year life: this is consistent with general NZ practice, including prevailing practice in AKL and PTOM contract proposals. • As for LRV, annual capital charge calculated on an annuity basis. Due to off-setting factors, the annual capital charge/ bus is very similar to the project team figures (for both standard and double-decker buses).

C. OPERATING RESOURCES			
1.	LRT mode	• The project team estimated annual operating resources for the LRT operation in the planning year (2046) as: ○ Peak vehicles 49 (plus 10% spare vehicles) ○ Service hours 181,000 pa (includes 10% for layover between trips) ○ Service km 2.94 million pa ○ Route km 32.1km	• Based on the project team passenger capacity standard (300/vehicle), peer review estimated slightly (6%-7%) lower operating resources required. On proposed adjusted standard (240/vehicle), peer review estimates were 60 PVR and similar service hours and service km to project team.
2.	Bus mode	• Project team estimate of bus operating resources saved by adoption of LRT scheme was: ○ Peak vehicles 254 (plus 10% spare vehicles) ○ Service hours 724,000 pa ○ Service km 10.92 million pa • No allowance appears to have been made for the residual (feeder) bus services that would be required at the southern end of the corridors served by LRT[(1)].	• Peer review estimates of (gross) bus operating resources saved by adoption of LRT were quite substantially (c. 38%) higher than project team estimates. • Peer review also estimated resources for residual (feeder) bus services required (based on project team specification for these services). After allowing for these services, peer review estimates of net bus mode resource savings remain higher than project team estimates, by c. 13%.
D. UNIT OPERATING COSTS			
1.	LRT mode	• The project team LRT operating cost model (based mainly on 1999 UK data), excluding vehicle capital charges, was as follows: Opex = $3.41 * service km + $49.20 * service hr + $90,500pa * route km For the proposed operation, this gives an average cost of $7.43/service km.	• The peer review team developed an average cost model based principally on recent information from Australian LRT systems, both those currently in operation (Melbourne, Adelaide, Gold Coast) and those in the planning/procurement stage (Sydney, Canberra). This work showed a range of operating costs of A$16-26 per service km. From this information, it was judged that the best estimate cost for the AKL scheme was about NZ$22 per service km. This figure is almost three times the project team average cost estimate.
2.	Bus mode	• The project team bus operating cost model (derived from AT sources) was as follows: Opex = $2.10 * service km + $41.00 * service hour Our understanding is that each of these cost items includes a component for bus operations overheads.	• The peer review team reviewed the project team model, including using recent data on bus operator costs both in AKL and elsewhere in NZ. It was concluded that: ○ The project team costs should be reduced by c. 5% to reflect recent AKL operator cost information. This adjustment was adopted for our main cost estimates. ○ A further cost reduction of up to 20% would be appropriate to match NZ efficient benchmark cost rates: this was used in sensitivity testing.
E. TOTAL OPERATING (INCLUDING VEHICLE) COSTS			
		• The following table presents the project team main estimates of operating costs (including vehicle capital charges) for the representative year of 2046 – comparing the LRT option with the bus option for the corridors concerned.	• The following table presents the peer review main cost estimates, on a comparable basis to the project team estimates for 2046.

	<table><tr><th rowspan="2">Cost category</th><th colspan="2">Annual Costs $M</th></tr><tr><th>Bus Option</th><th>LRT option</th></tr><tr><td>Bus – op costs</td><td>52.6</td><td>--</td></tr><tr><td>Bus – cap charges</td><td>14.7</td><td>-</td></tr><tr><td>LRT – op costs</td><td>--</td><td>21.8</td></tr><tr><td>LRT – cap charges</td><td>--</td><td>14.4</td></tr><tr><td>Total costs pa</td><td>67.3</td><td>36.2</td></tr></table>	<table><tr><th rowspan="2">Cost category</th><th colspan="2">Annual Costs $M</th></tr><tr><th>Bus option</th><th>LRT option</th></tr><tr><td>Bus – op costs</td><td>68.7</td><td>12.7</td></tr><tr><td>Bus –cap charges</td><td>17.7</td><td>3.2</td></tr><tr><td>LRT – op costs</td><td>--</td><td>65.5</td></tr><tr><td>LRT –cap charges</td><td>--</td><td>34.9</td></tr><tr><td>Total costs pa</td><td>86.4</td><td>116.4</td></tr></table> • The principal sensitivity tests undertaken by the peer review on the above estimate found: ○ Increasing LRV capacity from 240 to 300 (used by the project team) would reduce the (LRT-Bus) cost differences by c. $13 Mpa. ○ Using double-decker buses in place of standard buses in the bus option would increase the (LRT-Bus) cost differential by c. $33 Mpa. ○ Reducing bus operating costs (excl capital charges) by 20% (as in efficient benchmark cost estimates) would increase the (LRT-Bus) cost differential by c. $11 Mpa.
F. INFRASTRUCTURE CAPITAL COSTS		
1. LRT option	• Three sets of estimates were made by the project team of the infrastructure (‘design and construction’) costs for the LRT schemes, as follows (NZ$2014): ○ WT Partnership (initial, corrected): $1631 million ○ Turner & Townsend (peer review): $3305 million ○ WT Partnership (final, adjusted): $2606 million Our understanding is that the last of these figures has been adopted as the ‘definitive’ estimate at this stage of project development.	• The peer review of the project team infrastructure cost estimates considered the recent Australian evidence on infrastructure costs for recent and planned LRT schemes. It was concluded that the final/adjusted WT Partnership cost estimate of c. $2.6 Billion is broadly consistent with the review’s expectations based on the Australian evidence and allowing for the AKL situation. Some further work is recommended to fill a number of ‘gaps’ in this estimate and to provide a higher level of confidence.
2. Bus option	• For the alternative (bus) option, it appears that a literal ‘Do Minimum’ approach has been taken, which involves no significant infrastructure costs.	• The peer review understands the approach taken by the project team of assuming a literal ‘Do Minimum’ option against which the LRT option is compared. However, we would note that, if it were to be decided to continue to operate buses as the main mode in the corridors concerned over the next 30 years, then undoubtedly some significant infrastructure costs would be appropriate to enhance conditions for bus users.

Note: (1) It is possible that the project team has made an allowance, which has been netted off in deriving the above resource estimates, but this is not apparent from the documentation provided.

1. INTRODUCTION

This paper has been prepared for Auckland Transport by consultants Ian Wallis Associates (IWA), as part of a peer review of AT's proposals for a light rail network for Auckland.

The paper is one of three papers prepared by IWA for this peer review.

This paper (C) is concerned with **cost estimates**. Specifically it addresses the following aspect of the peer review task:

> *"Whether the estimates of incremental public transport capital costs (infrastructure and vehicles) and operating costs, relative to the bus-based base case, are sufficiently robust for this stage of option assessment".*

It reviews the cost estimates prepared by the AT project team for the LRT option and the alternative bus option, under three main cost groups, ie:

- Operating costs
- Vehicle capital costs
- Infrastructure capital costs.

For each of the cost groupings, the review examined whether the project team cost estimates are sufficiently robust at this stage of the project assessment, by comparing the estimates against cost data for operational LRT schemes in NZ and Australia. Where the cost estimates appear inconsistent with this evidence, we provide estimates, at an indicative level, that appear more appropriate.

The other two papers in this peer review set cover the following aspects of the AT proposals:

Paper A: Robustness of the deficiency analysis. This paper focuses on demand and capacity analyses regarding the maximum number of buses that can practically and reliably be accommodated on main routes in the isthmus and city centre.

Paper B: Options and assessment. This paper examined the reliability of the options analysis results in terms of the achievement of the study objectives, including whether all viable options have been considered and the appropriateness of the multi-criteria analysis (MCA) assessment methodology.

2. TASK STRUCTURE & METHODOLOGY

[This chapter to be reviewed.]

2.1. Overview of LRT option

The new LRT system key parameters assumed included:

- 33.64km double track (32.06km used in OPEX model)
- 54 LRV (49 peak), each vehicle capacity 300 passengers
- 35 substations
- 43 stops
- 1 initial temporary depot in phase 1
- 1 permanent depot developed phase 2

The introduction of the LRT system will result in a restructure and reduction in urban bus services resulting in the removal of 254 peak buses (279 total buses including spares) of 50 passengers capacity each.

2.2. Task Structure

This task is split into the following work streams:

- OPEX (Operational)
- CAPEX (Capital)
- Vehicle CAPEX

OPEX for Bus and LRT option incorporates the following costs:

- **Staff** costs (all)
- **Depot** rental, rates, taxes, cleaning, maintenance, repair, utility costs (both for Bus and LRT)
- **Route infrastructure** (track, overhead, substations, points, structures, cleaning, maintenance, repair, renewal, utilities etc. for LRT)
- **Control centre** (Operations and power control centre – LRT only) maintenance, repair, cleaning, renewal, utilities etc.
- **Light Rail Vehicle / Bus** maintenance, renewal, repair, renewal, power

CAPEX for LRT incorporates the following costs:

- **Depot** construction and commissioning costs
- **Control Centre** construction and commissioning costs (possible to be incorporated within Depot)
- **Route Infrastructure** construction and commissioning
- **Structure** such as tunnels, bridges, culverts etc.

Land procurement of all land required for Depot, substations and route alignment as well as any work required to prepare for construction work such as addressing environmental issues (if any) Vehicle CAPEX incorporates:

- **Light Rail Vehicle / Bus** procurement, commissioning, depreciation, finance, lease costs

NB: Light Rail Vehicle Battery & "wire free" technology is assumed to apply to the LRT option

2.3. Methodology

Methodology applied is based on:

- Initial review of material provided by project team

- Referencing the cost model and supporting material provided by the project team for the OPEX and CAPEX (LRT) scope:
    - OPEX (Bus and LRT option): Key documents and model and in particular:
        - Excel model "CCFAS2 costing sheet Option 4 Staging v4 (2-02-2015)"
        - PDF "Costing Summary for Option 6, 8, 9A, 4 – Revision (1.2)"
        - Q&A with project team as necessary
    - CAPEX (LRT option only): Key documents / model used including:
        - Excel model "Draft Estimate – 22.12.2014"
        - PDF "Report for Peer Review of Draft CAPEX Estimate" (Turner & Townsend – 23 December 2014)
        - Various other reports provided
        - Q&A with project team as necessary
    - Vehicle CAPEX:
        - Extract holding and funding costs from OPEX model and shown separately
- Based on experience of IWA team making comparisons to other systems (bus and light rail) within Australia and New Zealand.
- Using Auckland bus operator benchmark costs provide reworked indicative model for Bus OPEX.
- **Note however** that the proposed Auckland solution as per CAPEX model is a 100% "wire free" system. Auckland are planning for a battery / recharging station solution. IWA are unaware of other 100% similar ("wire free") LRT systems in world. IWA in reviewing the costs within the excel model developed relied upon advice from "supplier" experts. IWA also note that the CAPEX peer review consultant (Turner & Townsend) identified the same issue (refer report for "Peer Review of Draft Capex Estimate", 23 December 2014).

3. VEHICLE TYPES AND CAPACITIES

3.1. Buses

3.1.1. Project team assumptions

The project team considered two generic bus types, ie:

- 'Standard' size buses, similar to the majority of current Auckland fleet, with c. 37 seats and an effective planning capacity of 50 passengers.[1]
- Double-decker buses, with c. 90 seats and an effective planning capacity of c. 100 passengers.[2]

The project team assumptions are set out on Table 3.1.

The standard size buses were assumed in all the project team's main analyses.

3.1.2. IWA assessment

For the **standard** bus category, IWA reviewed planning capacity standards adopted for such bus sizes in the main Australasian centres. Taking the Wellington fleet as an example, it was found that seating capacity of 'standard' size buses varied between 37 and 51 seats, with standing capacity (@ 4 passengers/m^2) varying between 15 and 28 passengers. On this basis, IWA considers that a planning capacity figure of 50 passengers (average load/bus over AM peak 1-hour, peak direction, at point of maximum loading), as adopted by the project team, is reasonable for current planning purposes for this project.

For the double-decker bus category, again we consider that the project team's assumption of a 110 (90 + 20) nominal capacity vehicle is reasonable. On this basis, we assume a planning capacity of 100 passengers (ie including 10 standees, equivalent to 2 standees/m^2 on the lower deck).

For the **double-decker** category, it appears that the project team did not consider this option in any detail, and did not undertake any cost analyses (relative to the standard size buses). Given the passenger volumes anticipated in the relevant corridors, it would appear that the economics of double-decker buses is likely to be very favourable relative to standard size buses, and this solution would be more analogous to the LRT solution. We have therefore analysed the operational and cost implications of operating the main services in the corridors of interest with DD vehicles, at least in the peak periods, and then compared the results with the 'standard' bus and the LRT options.

We have therefore used planning capacities of 50 passengers (standard buses) and 100 passengers (DD) in our service analysis and cost modelling work.

3.2. LRV

3.2.1. Project team assumptions

The project team key assumptions on LRV, based on advice from Arup[3], were as follows:

- Vehicle length — 45 metres (7 modules, 100% low floor)
- Vehicle width — 2.65 metres
- Vehicle capacity — 300 passengers, based on all seats occupied plus standees @ 4/m^2 of available floor area[4].

[1] Project team specification (based on ADL Enviro 200 vehicles) is for buses with 37 seats and 18 standee spaces (@ 4/m^2). For service planning and costing purposes AT has taken average MLP capacity as 50 passengers.

[2] Project team specification refers to a triple axle double-decker vehicle (12.8m) with capacity for 90 seats and 20 standees @ 4/m^2. We assume an effective planning capacity of 100 passengers for such a vehicle

[3] Memo from Arup (Andy Wood) 'LRV Assumptions for CCFAS2', 3 Sept 2014.

[4] Arup noted that an appropriate loading standard for structure design is 6 standees/m^2.

All The project team assumptions are set out in Table 3.2.

3.2.2. IWA assessment

We have no issues with the project team assumptions on LRV length and width.

The team assumption on vehicle capacity is based on 4 standees/m^2, which is a standard often quoted by LRV suppliers. It represents quite a crushed loading level (but less than the structural design load of 6/m^2 often used). It is not realistic as a planning standard (average passengers/vehicle over peak 1 hour, peak direction) in Australasian conditions. Such a planning standard, which is relevant here, has to allow for the variability in loading levels both through the peak (1 hour) period and within each vehicle.

We reviewed the Australasian evidence on loading standards for planning purposes in current LRT (and urban rail) systems, principally Melbourne (commonly quoted as the world's largest tram/LRV system). In summary, our findings were as follows:

- The modern Melbourne trams are exemplified by the 'E' class[5], which are 33 metres long, have 64 seats and have total planning capacity (peak 1 hour average at maximum load point) of 180 passengers. This represents 2.87 standees/m^2 of available floor area or 5.29 total passengers/m length (with about 36% of total load being seated).
- The 'E' class trams have higher planning load standards than the earlier (still operational) Melbourne trams: the earlier trams (dominated by A, Z and B classes) average around 2.15 standees/m^2 or 4.55 total passengers/m length (with about 62% of the maximum load being seated).
- In Wellington, the urban rail system adopts a nominal loading standard of 2.55 standing passengers per m^2 of standing area; but GW then suggests that the resulting total load figures should in future be factored by around 0.85 to allow for 'loading diversity'[6]. The outcome would be for a planning load standard (peak 1 hour average) of well under 2.0 standees/ m^2.[7]
- For the Auckland urban rail system, advice received was that, for future service planning, a ratio of 7 standees to 10 seated passengers (ie 59% of total passengers being seated) should be adopted, and that this approximately equates to 2.5 standees/ m^2.
- We note that, as the typical passenger travel times on the AKL and WGN urban rail systems are typically longer than is likely on the LRT system, this may justify a somewhat less generous (higher) loading standard for the LRT.

Our conclusions on this aspect are that, for LRT service planning purposes at this stage:

(i) A standard of 4 standees/ m^2, as assumed by the AT project team, is not sufficiently generous (and likely to be very unpopular with actual and potential users).

(ii) Standards based on current operating practice for new trams in Melbourne would be more appropriate. Based on the new E class trams, this would involve a standard of around 5.3 total passengers/metre length (and around 2.9 standees/m^2 of available floor area).

(iii) This would result in a capacity standard of about 240 passengers per 45m tram: this is a reduction of some 20% from the 300 capacity assumed by the project team.

In the light of this conclusion, we adopt this revised standard in our subsequent cost assessment work. Table 3.2 indicates (based on the Melbourne E trams) our approximate breakdown of the 240 passengers figure between seated (36%) and standing passengers.

---

[5] About 17 E class trams are now in service, and PTV's intention is that the entire fleet will comprise E class trams in future.

[6] The current 'loading diversity' factor adopted in Wellington is, de facto, lower than 0.85. It is expected that the 0.85 factor will be appropriate when the more frequent peak services proposed are implemented.

[7] GWRC 'Wellington Regional Rail Plan 2010 – 2035'. 2013 edition.

TABLE 3.1: BUS TYPES AND PLANNING CAPACITIES					
Item	**Project team**		**IWA assessment**		**IWA comments**
	Standard	**Double-decker(1)**	**Standard**	**Double-decker(1)**	
Length (m)	11.0	12.8	11.0	12.8	
Seats	37	90	37	90	
Standing area (m^2)	4.5	5.0	4.5	5.0	Lower deck only.
Standee rate/m^2	4	4	4	4	Standees not allowed on DD top deck
Standee rated capacity	18	20	18	20	
Standee planning capacity	13	na	13	10	
Total planning capacity	50	na	50	100	
Seated %	74%	--	74%	90%	

Note:

(1) Project team work [AT51] identified two distinct types of DD buses: (i) 12.8m triple axle BRT bus - 90 seat + 20 standing capacity; and (ii) 11.0m twin axle FTN bus – 62 seats + 15 standing capacity. Current Ritchie's AKL DD buses are Volvo, Malaysian body, 12.1 metres length, 86 seats.

TABLE 3.2: LRV TYPES AND PLANNING CAPACITIES			
Item	**Project Team**	**IWA Assessment(1)**	**IWA comments**
Length (m)	45.0	45.0	Noting comments by Arup, appears to be a reasonable assumption at this stage, giving a sensible balance between vehicle size and service frequency.
Seats	?	87	
Standing area (m^2)	?	52.6	
Standee rate/m^2	4.0	2.9	
Standee planning capacity	?	153	
Total planning capacity	300	240	
Seated %	?	36%	

Notes:

(1) IWA figures scaled up from the Melbourne E class trams (which are 33.0 m length).

4. VEHICLE CAPITAL COSTS

4.1. Bus Capital Costs

4.1.1. Project team estimates

The project team estimates for buses considered a 'standard' size bus (c. 40 seats) and a double-decker bus, and assumed:

- An effective (economic) life of 12 years in both cases.
- An initial purchase cost of $500,000 (standard) and $650,000 (double-decker).
- A 'half-life' renewal cost of 20% of the new cost in each case.
- The capital costs would be translated into annual capital charges, based solely on the historic cost depreciation over the life of the vehicles.

These assumptions are set out in Table 4.1. The result is annual capital charges per bus of $50,000pa for the standard bus size, and $65,000 for the double-deckers (ie 10% of the initial purchase price in each case).

4.1.2 IWA appraisal

Our review of the project team bus unit capital cost estimates found that:

- The effective life of buses should be taken as 20 years, consistent with the PTOM contract specification and the NZTA Requirements for Urban Buses in New Zealand (RUB) and the practices adopted in most other regions. The project team 12 year assumption is inconsistent with practices commonly adopted for urban route service buses in both NZ and Australia.
- The new prices assumed by the project team are on the high side for the standard (c. 40 seat) buses. Our best estimate is $440,000 for standard buses (based closely on bus prices paid by AKL operators in recent years). For double-decker buses, there is limited price data available in NZ: at this stage, we adopt the project team estimate of $650,000 as appropriate.
- As noted above, the project team derived an annual capital charge per bus based solely on the historic cost depreciation from the new price over the assumed life. We do not consider this approach is appropriate as it makes no allowance for the economic cost of capital or future inflation in bus prices. Our preferred approach (adopted quite widely elsewhere) is to estimate the capital charge on an annuity (mortgage) basis over the bus life, giving similar annual payments to those resulting if the buses were financed through a typical finance lease arrangement. The result is for a constant annual charge over the life of the bus of approximately 11% of the new bus price.
- As it happens, due to off-setting factors, our assessment of annual capital charges per bus is not very different from that of the project team: the project team figures were 10% of their bus purchase price (but not adjusted for inflation), ours equate to about 11%.

Our unit cost estimates per bus per year are set out in Table 4.1, for comparison with the project team estimates.

4.2. LRV Capital Costs

4.2.1 Project team estimates

As noted earlier (section 3.2), the project team assumed 45 metre length (2.65 metre width) vehicles (and we accept this is a reasonable assumption at this planning stage).

The vehicle capital cost estimate used in the project team costing model was $6.8 million, with an assumed life of 30 years. We also note that the WT Partnership estimated a unit cost of $6.13 million, based on a similar vehicle specification (this figure was not adjusted in the light of the Turner & Townsend peer review of the infrastructure costs).

We note that, for their costing model, the project team assumed:

- A cost allowance for vehicle 'renewal' after 15 years, of 20% of the initial vehicle costs (ie $1.36 million)[8]
- Straight line historic cost depreciation over the 30 year life, equating to $227,000pa per vehicle (plus $41,000pa for the half-life renewal).

These figures are shown in Table 4.2.

4.2.2 IWA appraisal

There are significant difficulties in estimating LRV capital costs for situations such as this, for the following reasons in particular:

- Most of the more recent LRV procurements in Australia have covered both vehicle supply and maintenance, with the result that the supply component of the costs is not separately apparent.
- The suggested AT proposals are for a 'wire free' LRT system. However, to our knowledge, there are no such systems of significant length operating anywhere in the world, and thus very limited information on both relevant vehicle costs and operational experience. Turner & Townsend also noted this difficulty in their Capex peer review. IWA has therefore had to rely on advice from selected suppliers as to the vehicle capital costs applicable in this situation.[9]
- Unit vehicle costs can be relatively sensitive to the size of the order, the maximum network grade and whether the vehicles are single- or bi-directional.

We have discussed likely costs for 45m LRVs for Auckland with a number of potential suppliers, and drawn the following conclusions:

- Typical prices for 'standard' 45m LRVs involving overhead wire operation from European/ American suppliers are in the range A$4.2 – A$5.0 million per unit.
- These figures are based on LRVs of generic design that are fitted in to production runs of the selected supplier; assume standard infrastructure configuration; are designed for bi-directional operation; and involve a minimum order of 10-15 units.
- For battery operations, costs would increase to about A$4.8 – A$5.6 million (two batteries would be required @ c. $0.3 million each)[10]. This translates (at a conversion rate of 1.10) to about NZ$5.3 - $6.2 million.

We also note that:

- These costs would reduce by c. 5% if bi-directional operation is not required.
- LRVs from Chinese or East European (eg Poland) sources are likely to cost in the order of 25% less than the above figures, without significant loss of quality.
- At any particular time, discounted or second-hand LRVs may be available (eg Adelaide purchased Alstom trams at a significant discount).

[8] The project team model sheet [AT44.2] states that the renewal allowance is 20% of the original cost (which should be $1.36 million). However, the figure shown in the cost spreadsheet is actually $1.226 million, which is about 18% of the original cost.

[9] We note suggestions that, while wire-free LRVs may be more expensive than comparable 'catenary' LRVs, the additional vehicle costs may well be more than compensated for by the savings in establishing and maintaining an overhead wire network.

[10] It is not clear whether there would be significant off-setting cost reductions if pantographs are not required.

- Currently batteries need to be replaced after c. 7 years. However, battery technology is developing rapidly, with increased battery life and reduced costs.

Based on the above, we consider that the $6.8 million figure used in the project team's costing is on the conservative side, even assuming wire-free operation, and a reduction in the order of 10% would appear more appropriate[11]. For convenience, we adopt the WT Partnership figure of $6.13 million in our further analyses.

[11] An additional reduction in the order of 10% could apply in the case of wired operation, although increased costs would be expected in other areas (eg maintenance of overhead wiring system).

TABLE 4.1: BUS UNIT CAPITAL COSTS					
Item	AT Team Assumptions[1]		IWA Estimates		IWA Comments
	Bus Type		Bus Type		
	Standard	Double-decker	Standard	Double-decker	
Economic life (years)	12 years	12 years	20 years	20 years	Standard economic life of NZ urban buses is 20 years (as in PTOM contracts, NZTA Regulations for Urban Buses – *[check]*
Capital costs ($000)					
Initial purchase	500	650	440	650	'Standard' bus prices based on recent prices being paid (or estimated) by AKL bus operators for 40-49 seater buses. Double-decker bus price estimates from other information (limited data available).
Half-life renewal (20%)	100	130	66	98	'Half-life' renewal would not usually apply to 12 year life; would generally apply to 20 year life, but less costly than AT assumption (have guestimated at 15% of purchase price).
Annualised charge – depreciation only ($000)					AT figures allow for (historic cost) depreciation only. More appropriate estimates would take account of the opportunity cost of funds, equivalent to the costs under a finance lease arrangement or similar. On this basis, our estimate of the annual charge over a 20-year bus life is about 11% of the capital expenditure (ie $440k/$650k for the two bus sizes).
Initial purchase	41.7	54.2			
Half-life renewal	10.8	14.0			
Total annual	52.5	68.2	45.7	67.5	

Note:

(1) As in CCFAS2 Costing sheet, Assumptions (IWA 44.2). These figures derived from AT email chain 13 Nov – 11 Dec 2014 (IWA 44.3).

TABLE 4.2: LRV UNIT CAPITAL COSTS			
Item	AT Team Assumptions[1]	IWA Estimates	IWA Comments
Economic life (years)	30 years	30 years	Arguably the effective life might be extended to 35 years (maybe more consistent with the bus life assumption of 20 years).
Capital costs ($000)			
Initial purchase	6800	6130	The project team $6.80 million figure is as used in the AT costing analysis: an alternative figure proposed (WT Partnership) was $6.13 million.
Half-life renewal (20%)	1226	1226	
Annualised charge – depreciation only ($000)			The AT figures are based on straight line depreciation on the historic cost. IWA figures are based on an annuity calculation, which would more closely reflect the annual costs under a finance lease (or PPP) arrangements.
Initial purchase	227	*[To add]*	
Half-life renewal	41		
Total annual	268	528.5	

Note:

(1) As in CCFAS2 Costing sheet, Assumptions [IWA 44.2].

5. OPERATING STATISTICS

Table 5.1 provides a summary of the net changes in annual operating statistics in the corridor of interest as a result of introducing the full LRT scheme proposed, deleting the directly-competing bus routes, and introducing a set of feeder bus routes to link with the southern ends of the LRT lines:

- The project team estimates of the change in bus operating statistics appear to have been made by just estimating the statistics for the full length of the present bus routes using the corridor: no allowance appears to have been made for the provision of new feeder bus routes to the LRT from the area currently served by bus routes south of the LRT termini.[12] Clearly this will overstate the net bus operations and cost savings resulting from the LRT proposals.
- The IWA estimates have been specifically calculated as the difference between (i) the 'base case' (no LRT) bus services in the corridor; and (ii) the residual feeder bus etc services if the LRT is implemented. We thus consider that these estimations for 'net bus services removed' are more realistic than the project team figures.

Table 5.1 shows the IWA operating statistics estimates both for the 'standard' bus case (ie comparable with the project team figures) and for the 'double-decker' case. For the DD case, we have adjusted the peak period frequencies on the main bus routes in response to the doubling of practical capacity per bus (from 50 to 100 passengers), and hence adjusted the PVR, service hours and service km statistics accordingly.

The table also shows the project team estimates for LRT operating statistics and two sets of IWA estimates:

- Based on the AT planning capacity of 300 passengers/vehicle, but with slight modifications to optimise the service plan (including reducing the PVR).
- Based on our suggested planning capacity of 240 passengers/bus (refer section 4.2.2). This results in a c. 25% increase in peak service levels (trams/hour) and corresponding increases in service hours and service km at peak periods.

The information given in Table 5.1 is used subsequently for the operating costs (including vehicle capital charges) assessment in chapter 6.

[12] For example, refer project team document CCFAS2 Costing sheet option 4 staging v4 (2-02-15) [IWA 44.1]

TABLE 5.1: ANNUAL OPERATING STATISTICS – Project team and IWA estimates

	Change in Annual Operating Statistics (2046)				Comments
	PVR	Service Hours[1]	Service Km[2]	Route Km	
BUSES					
AT project team:					Ex AT CCFAS2 costing sheet option 4 staging v4
Net bus services removed	254	723.9	10,921		Assumes 50 pax/bus (planning standard)
IWA review – single decker					Assume 50 pax/bus (planning standard), as AT
Services removed	352	993.3	14,991		
Services added	63	185.4	2,733		
Net services removed	289	807.9	12,258		
IWA review – double decker					Assumes double-deckers (except Queen Street) - assumes 100 pax/bus
Services removed	184	554.4	8039		
Services added	63	185.4	2733		Feeder services – assumes still use single decker buses.
Net services removed	121	369.0	5306		
LRT					Ex AT CCFAS2 costing sheet option 4 staging v4
AT project team (300 cap)	49	181.0	2935	32.06	Assumes 300pax/vehicle (planning standard)
IWA review – double-decker					
300 cap	46	168.7	2772	33.1	As AT
240 cap	60	182.7	2977	33.1	Assumes 240 pax/vehicle (consistent with MEL standards).

Notes:

(1) Includes allowance of 10% for layover between trips.

(2) No allowance included for dead (out-of-service) running.

6. OPERATING COSTS

6.1 Bus operating costs

6.1.1 Unit cost estimates – project team

The unit bus operating cost function (standard size buses, excluding capital charges) adopted by the AT project team is as follows (assumed in 2014/15 prices)[13]:

$2.10 * service km + $41 * service hour.

Further details and comments are provided in Table 6.1. We note in particular that:

- The basis for the figures is not well documented: some documentation is provided in an AT email chain, but the above cost rates (as applied) differ from those in the emails.
- It appears that the email rates are taken more-or-less directly from variable cost rates in the AT operator contracts. It is not clear to what extent these rates reflect 'marginal' costs or whether they include a full allocation of overhead costs. In any event, no separate allowance has been made for operating overhead costs, which for AKL contracted bus operators comprise around 24% of total operating costs.
- The project team rates are substantially higher than AKL operator direct costs for the corresponding cost categories – around 70% higher per service km and c. 20% higher per service hour.

TABLE 6.1: UNIT BUS OPERATING COSTS (STANDARD BUSES) – PROJECT TEAM ESTIMATES AND COMMENTS

Cost Category	Adopted Rate	Sources	IWA Comments
Bus R&M, fuel, RUC	$2.10/service km	AT emails (AT44.3) give figure of $2.00. Stated that this is based on variable rates in AT bus operating contracts. Basis for adjustment to $2.10 not clear.	This rate is very much (c. 70%) higher than recent rate information on direct operating costs of AKL contracted bus services, but it may include an allocation of (indirect) overheads.
Drivers	$41/service hr	AT emails (AT44.3) give figure of $30, which is said to include driver (direct?) overheads. Stated that this is based on variable rates in AT bus operating contracts. Basis for adjustment from $30 to $41 is not clear.	This rate is substantially (c. 30%) higher than recent rate information on direct operating costs of AKL contracted bus services, but it may include an allocation of (indirect) overheads.
Other operating costs (overheads, etc)	--	--	General operator overheads typically comprise around 24% of total costs (excl. cap charges) for AKL bus operators. While AT has not included these separately, it appears most likely they have been allocated across the above cost categories

[13] Source: AT email chain Bus opex CCFAS2, 13 Nov – 11 Dec 2014 [AT44.3]

6.1.2 Unit cost estimates – IWA review

For a bus operation reflecting the operating conditions (with an average service speed of c. 16km/hr) in the corridors of interest, we have compared the results of applying the project team cost assumptions with:

(i) IWA's best estimates of unit costs for AKL bus operators (drawn from various confidential information sources); and

(ii) IWA's estimates of 'efficient' NZ bus operator unit cost rates (drawn from IWA's NZ bus operating costs database).

Our main findings and conclusions for 'standard' size buses are:

- The project team operating costs are c. 5% higher than IWA's best estimates of actual AKL bus operator costs over recent years.
- There would appear to be potential for current AKL bus operator costs to reduce by up to c. 20%, in order to reach efficient NZ bus operator cost rates. It is not clear at this stage to what extent this reduction will be achieved in the forthcoming tender/negotiation rounds (under the PTOM regime).
- On this basis, we suggest that (for standard size buses):
  - For an improved costing assessment (based primarily on current AKL bus operator costs), a 5% reduction in the project team unit operating costs should be made.
  - As a sensitivity test, a further reduction in unit operating costs of 20% (to meet efficient NZ cost standards) should be applied.

6.1.3 Total bus operating cost comparisons ('standard' buses)

Based on the above, Table 6.2 presents a summary of bus costing estimates (for the full stage 5 scheme). It provides estimates of annual operating statistics for two operating cases:

- Project team case (as documented).
- IWA review case. These are somewhat (c. 12%) higher than the project team estimates, despite adjusting for the feeder bus requirement.

Unit operating costs (including bus capital charges) are provided for three cases:

- Project team case (as documented, discussed above).
- IWA typical AKL operator case – taken as 5% less overall than the project team case (refer above).
- IWA 'efficient' case – taken as 20% less overall than the typical AKL operator case (as discussed above).

Key features of these results include the following:

- Our estimate of the net annual bus operations costs (including vehicle capital charges) based on the project team operating statistics and unit cost rates is $67.28 Mpa, which is effectively identical to the project team figure ($67.26M) –as would be expected. (It should be noted that these figures, as for the other results given in this section, represents the **net** cost for bus services in the corridor of interest, ie it is the costs for a bus option in the corridor **less** the costs that would be required for feeder bus operations for the LRT option.)
- This figure reduces to $62.75 Mpa on the basis of IWA's typical AKL unit bus cost rates (involving a 5% reduction in unit operating costs from the AT figures, and 13% lower unit bus capital charges).
- But the total figure would be higher, at $70.45 Mpa, using the IWA AKL unit costs and IWA's higher estimate of operating statistics.

TABLE 6.2: BUS OPERATING COST SUMMARY – PROJECT TEAM & IWA REVIEW. (All figures relate to full (stage 5) proposals, on annual basis)

Item	Unit Costs	PVR(4)	Service Hrs(1) (000)	Service Km (000)	Totals $Mpa
A. 'STANDARD' BUSES					
Operating statistics					
AT project team:					
Net services removed		254	723.9	10,921	
IWA review:					
Services removed		352	993.3	14,991	
Services added		63	185.4	2,733	
Net services removed		289	807.9	12,258	
Unit cost rates	AT project team	52,500	41.00	2.10	
	IWA review - typical AKL	45,700	38.95	2.00	
	IWA review - efficient	45,700	31.16(7)	1.60(7)	
Aggregate costs ($Mpa)					
Project team	Project team	14.67	29.68	22.93	67.28
Project team	IWA review - typical AKL2	12.77	31.47	24.52	62.75
IWA review	IWA review - typical AKL	14.53	31.47	24.52	70.45
IWA review	IWA review - efficient AKL	14.53			59.27
B. 'DOUBLE DECKER' BUSES					
Operating statistics					
IWA review:					
Services removed(5)		184	554.4	8039	
Services added(6)		63	185.4	2733	
Net services removed		121	369.0	5306	
Unit cost rates	IWA review - typical AKL	67,500	40.90	2.59	
(double-decker)	IWA review - efficient	67,500	32.72	2.07	
Aggregate costs ($Mpa)					
IWA	IWA - typical AKL				
	Services removed	13.66	22.67	20.82	57.15
	Services added	4.68	7.58	7.08	19.34
	Net services removed	8.98	15.09	13.74	37.81
IWA	IWA – efficient rates				
	Services removed	13.66	18.14	16.64	48.44
	Services added	4.68	6.07	5.66	16.41
	Net services removed	8.98	12.07	10.98	32.03

Notes:

(1) Includes allowance for terminal time, at 10% of timetable time.
(2) Taken as 5% off project team estimate (refer text), but excluding capital charges
(3) Taken as 20% off IWA typical AKL figure (refer text), but excluding capital charges
(4) Figures given relate to peak vehicle requirement (PVR). These are increased by 10% to allow for spare buses.
(5) These services are DD operation
(6) These services are assumed SD operation.
(7) Relative to the line above.

- This total would then reduce, to $59.27 Mpa, based on IWA's efficient cost rates (unit operating costs 20% lower than the IWA AKL current unit costs).

  In summary, we conclude that the project team estimate of net costs for the (standard) bus option of about $67.3 Mpa, is reasonably robust at this stage of the project planning process[14]: the range of estimates we have made are all within +5%/-12% of the project team's net total.

6.1.4 Implications of larger (double-decker) buses

As an important sensitivity test, we have examined the implications in the bus option of deploying larger buses on the main corridor (line haul) bus services, while retaining 'standard' size buses on the bus feeder routes proposed under the LRT option. Our assumption is that the 'larger' buses would comprise double-decker buses, with about 85-90 seats and an effective capacity for planning purposes of c. 100 passengers (refer section 3.1).

We have also estimated (but without the benefit of detailed information) that the capital costs for double-decker (DD) buses would be 30% higher than for 'standard' buses (this is consistent with the project team assumption), and unit costs/service km would be 30% higher and driver costs per service hour would be 5% higher than for standard buses (the project team does not make estimates of any operating cost differences).

The results of our sensitivity tests, based on these estimates, are given in the lower part of Table 6.2. It is seen there that:

- Based on IWA's estimated operating statistics and the DD-specific passenger capacity and unit cost factors (starting from IWA's AKL unit cost figures), the net bus operating cost would reduce from $70.5 Mpa for the standard buses to $37.8 Mpa with DD buses on the line haul services.
- Similarly, based on IWA efficient costs, the reduction would be from $59.3 Mpa to $32.0 Mpa.
- The main factor 'driving' these cost reductions is the doubling of effective capacity/bus (with the planning standard for a DD bus of 100 being twice that for a standard bus of 50).
- This saving is only partially off-set by the increased unit costs for DD buses – which average around 22% per bus service km.
- The favourable result also reflects the net contribution of line haul services (which would be deleted under the LRT option) and feeder services (which would be added).

These results would indicate a strong case for further work to be done to evaluate a DD-based solution in more depth.

6.2 LRT operating costs

6.2.1 Unit cost estimates – project team

The AT project team formulated an LRT operating cost model (excluding LRV capital) based essentially on three cost 'drivers', ie:

- Service km – which is the 'driver' of vehicle power and R&M costs.
- Service hour – the 'driver' of tram operations (essentially driving staff) costs.
- Route km – the 'driver' of all infrastructure maintenance and renewals.

The first two components are consistent with the approach taken in the project team's bus costing model; while the third component is essentially replaced in the bus costing model by RUC, which is there treated as variable with service km.

Table 6.3 sets out further details of the components of the project team's LRV cost model.

[14] In our view, this apparent 'robustness' in qualitative terms is partly the outcome of lower operating statistics and higher unit costs than our estimates.

We consider that the structure of the project team's cost model is reasonable at this stage of the planning process, but we consider the work undertaken to formulate the chosen rates is generally inadequate and lacking robustness. The main basis for the rates appears to be a note by Arup, based on some 1999 UK cost rates, which have then been inflated (by UK CPI statistics?) and converted to NZ$ figures (using standard exchange rate information).[15] There appears to have been no attempt to make any use of more recent Australian data sources, either for LRT systems already operating (eg Melbourne) or for systems currently in the development stage (eg Sydney, Canberra): this is surprising.

IWA was unable to review the project team unit cost estimates on a component-by-component basis, as minimal information was provided on the basis of their derivation. However, we have provided some brief comments on each of the project team components in the RH column of Table 6.3.

TABLE 6.3: UNIT LRT OPERATING COSTS – PROJECT TEAM ESTIMATES AND COMMENTS

Cost Category	Adopted Rate	Sources	IWA Comments
Tram R&M	$1.10/service km	AT44.2. Based on Arup advice (GB 1999 data) adjusted for inflation and currency conversion.	Based on Australian benchmarking tram R&M ranged between A$2.00 and $2.70 per service km (2013/14 rates)
Tram power	$2.31/service km	AT44.2. Based on power consumption 7 Kwh/km, price 30¢/kwh, plus allowance of 10% for station and depot power.	Benchmark power consumption rates from Australian evidence ranged between 5.6 Kwh/km to 6.8 Kwh/km for Tram. Thus consumption estimate used is reasonable.
Tram staffing (drivers)	$49.20/service hr	AT44.2. Assumed as for bus plus 20% uplift.	Australian tram driver benchmark (2013/14) rates of drivers ranged between $53 and $64 per service hour.
Network infrastructure maintenance	$66,000pa/double track route km	AT44.2. Based on Arup advice (GB 1999 data) adjusted for inflation and currency conversion.	Benchmarked infrastructure maintenance cost per track km varied between $100k pa and $200k pa (inclusive of renewal). Most benchmarked costs are based on operating contracts below 20 years.
Network infrastructure renewals	$24,500/double track route km	AT44.2. Based on Arup advice that c. 37% of network infrastructure maintenance.	

6.2.2 Unit cost estimates – IWA review

Our approach to reviewing the project team's LRT unit operating cost estimates was essentially to derive independent estimates of operating cost rates, based largely on data from existing and planned Australian LRT systems, and making some allowance for cost differences between Australian and New Zealand cost environments where appropriate. We note that our costs for most of the Australian systems considered were based on data from experienced international LRT operators. Rather than trying to base our assessment on the project team's various cost 'driver' categories, we took a more aggregate approach, using operating costs/service km as our primary cost unit. We found that the range of average costs (per service km) for the Australian systems examined was quite wide, between about A$16 and A$26 per service km (excluding LRV capital-related costs). On consideration of the data, the systems covered and the environment of the AKL project, IWA's 'best estimate' of likely costs for the AKL project is around NZ$22 (2014/15) per service km. We note that a fairly wide level of confidence applies to this estimate at this stage: it should be possible to significantly refine this

[15] The tram driver unit rate was an exception to this, being based directly on the project team unit rate for bus drivers (per service hour), with a 20% assumed increase.

estimate, and its confidence interval, through a more detailed benchmarking exercise involving selected Australian LRT systems.[16]

Our 'best estimate' figure of $22/service km may be compared with the project team figures, which result in an average cost of $7.43/service km[17] (ie only about one-third of our estimate).

6.2.3 Total LRT operating cost comparisons

Based on the above, Table 6.4 presents a summary of LRT costing estimates for the full (stage 5) scheme – these estimates cover the LRT service costs only, and exclude the associated feeder bus services (which were covered in the earlier section).

The table provides estimates of annual operating statistics for three cases:

- Project team estimates (as documented) - based on practical vehicle (45m) planning capacity of 300 passengers.
- IWA adjusted estimates, based on re-working of the proposed service plan (slightly lower operating statistics), with 300 passenger planning capacity.
- IWA 'improved standards' estimate, with passenger planning capacity reduced to 240 per vehicle (45m) resulting in about 30% increase in PVR and about 8% increase in service hours and service km.

Two sets of unit costs have also been applied:

- Project team unit costs, as applied in their cost assessments.
- IWA average cost estimate, with operating cost of $22/service km as noted above plus a vehicle capital charge estimated on an annuity basis.

The lower section of the table sets out annual LRT operating costs (including vehicle capital charges) based on various combinations of the three sets of operating statistics and two sets of unit costs. Key findings are summarised as follows:

- Based on the project team LRV capacity assumptions, operating plan and unit cost rates, the annual cost is $36.24 Mpa, which is virtually identical to the team's own estimate ($36.25 Mpa), as would be expected.
- However, when the IWA unit cost rates are applied, major increases in this estimate result, reflecting IWA's much higher estimates for both unit operating costs and vehicle capital charges.
- The IWA best estimate, based on the vehicle capacity standard of 240 passengers and IWA's best estimate unit cost figures, is for an annual LRT cost of $100 M. This would reduce to $88M if the 300 passenger capacity standard (as adopted by the project team) were to be applied.

[16] The indicative cost estimate range of between $16 and $26 per km can be for a variety of reasons including the difference between industrial awards (which are state based in Australia), dead running differences, fleet size and age, infrastructure design and age, average speed and whether the operator is responsible for ticket sales and revenue protection activities amongst others.

[17] $21.804 Mpa for 2.935M service km: refer AT CCFAS2 costing sheet option 4 staging v.4 (02.02.2015) [Ref AT 44.2]

TABLE 6.4: LRT OPERATING COST SUMMARY – PROJECT TEAM & IWA REVIEW. (All figures relate to full (stage 5) proposals, LRT services only on annual basis)

	Change in Annual Operating Statistics				Totals
	PVR	Service Hours[1] (000)	Service Km[2] (000)	Route Km	
AT project team:					
300 cap	49	181.0	2935	32.06	
IWA review					
300 cap	46	168.7	2772	33.1	
240 cap	60	182.7	2977	33.1	
Unit cost rates					
AT project team	267.5	49.20	3.41	90,500	
IWA review	528.5	--	22.00	--	
Aggregate costs ($Mpa)					
AT ops (300), AT UC	14.42	8.91	10.01	2.90	36.24
AT ops (300), IWA UC	25.90	--	64.57	--	90.47
IWA ops (300), IWA UC	26.74	--	60.98	--	87.72
IWA ops (240), IWA UC	34.88	--	65.49	--	100.37

Notes:

(1) Includes allowance of 10% for layover between trips.

(2) No allowance included for dead (out-of-service) running.

7 INFRASTRUCTURE CAPITAL COSTS

The draft cost estimate provided was developed and supported through a useful and detailed excel model however no supporting detail was provided by WT Partnership that could be used to evaluate the LRT CAPEX model basis and assumptions. A LRT system scope and specification paper was not provided for peer review to support the model. The parameters sighted were high level that IWA considered was not ideal for a subsequent peer review process.

A peer review was previously carried out by Turner & Townsend on the initial CAPEX model prepared by WT Partnership. It appeared from reviewing this work that Turner & Townsend had direct access to WT Partnership whereas IWA due to scope and time constraints of task relied upon materials provided.

The Turner & Townsend review provided a materially different view on an appropriate CAPEX cost estimate for the proposed LRT system.

IWA notes that the WT Partnership CAPEX model assumed a 'wire free' system.

Subsequently, after reviewing the peer review report IWA notes that WT Partnership provided an adjusted cost estimate having taken into account the peer review feedback provided by Turner & Townsend. This resulted in a significantly higher CAPEX than the original estimate but was still less than the Turner & Townsend (peer review) estimate. IWA is of the view that this adjusted estimate ($2,626m / $78.07m per route km) is a reasonable cost estimate at this early stage of the project.

7.1 Project team estimates

The draft CAPEX estimate model was prepared by WT Partnership and subsequently reviewed by Turner & Townsend. Table 7.1 provides a high level comparison outcome between the 'initial' WT Partnership model and the Turner & Townsend estimate.

The version peer reviewed by Turner & Townsend was the initial version dated 2/12/2014. The subsequent version (22/12/2014), adjusted after reflecting on the peer review paper, was materially different at $2,626m (compared to the initial version $1,614m).[18]

The WT Partnership initial cost estimate (2/12/2014) for Option 4 was $1,614m whilst the peer review (Turner & Townsend) provided a cost estimate of $3,305m. The initial cost of $1,614m was increased by Turner & Townsend to $1,631m being the correction of a mathematical error within the initial cost estimate model: Table 7.1 shows the initial cost estimate and the Turner & Townsend estimate.

Table 7.1 CAPEX comparisons: WT Partnership and Turner & Townsend review

(NZ$000's)	WT Partnership cost estimate 2/12/14	Turner & Townsend peer review
Direct construction costs		
Track (33.64 km alignment)	352.1	211.5
Power (inc. 35 Nr substations)	76.2	285.6
Systems	19.8	90.8
Utilities	63.7	326.8
Roadworks	13.9	47.5
Stops (43 Nr)	54.9	59.4
Depot & Stabling Facility	74.4	105.8
Direct construction costs	**655.0**	**1,127.4**
Preliminaries	156.4	414.9
Traffic management	29.5	50.7

[18] Both these figures have been adjusted to remove the LRV costs from the model.

Contractor's design	26.2	202.9
Indirect construction costs	**212.1**	**668.5**
Total construction costs	**867.1**	**1,795.9**
Contractor's OH&P	130.1	269.4
Total contractor's costs	**997.2**	**2065.3**
Planning & Development	29.9	41.4
Client Design	29.9	60.8
Client Costs	20.0	92.5
Owners management costs total	**79.8**	**194.7**
Subtotal	**1,076.9**	**2,260.0**
Property acquisitions	282.3	282.3
Subtotal	**1359.3**	**2,542.3**
Risk and contingency	271.9	762.7
Subtotal	****1,631.2**	**3,305.0**
Track km	33.64	33.64
D&C cost ($m) per km	48.49	98.25

Within the Turner & Townsend peer review report explanations were provided justifying the differences in assessed costs. As well, within the Turner & Townsend report the presentation was in a different format than provided by WT Partnership. For changes made subsequently by WT Partnership, refer Table 7.2 in which they retained in the same format as initially presented.

Table 7.2 CAPEX comparisons: WT Partnership initial and updated costs

All costs $m	WT Partnership initial cost estimate (2-12-2014)	As per draft estimate model provided (WT Partnership 22-12-2014 updated cost estimate)
Land & Property	282.3	281.97
Investigation & Reporting	29.9	39.39
Developed Design & D&C Monitoring	49.8	118.18
Design & Construct contract	**362.0**	**439.54**
Track (34 km alignment)	352.1	238.03
Power (inc. 35 Nr substations)	76.2	279.17
Systems	20.1	50.77
Statutory Undertakers Equipment	63.7	102.77
Highway Costs	13.9	105.84
Stops (43 Nr)	54.9	76.50
Support Facilities	74.4	79.85
Design	26.2	121.28
Programme & Project Management	185.9	316.03
Subtotal	**867.5**	**1,370.24**
Off site overhead and Profit	130.1	205.54
Total D&C	**997.6**	**1,575.77**
Contingency P50	254	610.84
Subtotal @4Q14 prices	**1,613.6**	**2,626.16**
Track km	33.64	33.64
D&C cost ($m) per km	47.97	78.07

***NB: Difference in Turner & Townsend initial cost estimate of $1,613.6 and $1,631.2 in above table (8.1) was due to the original cost estimate having a mathematical error subsequently corrected.*

Within the peer review report and the subsequent adjustments of the WT Partnership model (within the Excel model) justification for differences assessed and subsequently made can be traced. IWA makes no judgement on the peer review assessment and changes subsequently made other than to compare to Australian indicative CAPEX costs and methodology used (refer section 7.2 following).

Note that if the WT Partnership adjusted estimated cost dated 22/12/2014 was used then the variance between the peer review and their CAPEX would be a much closer outcome to the Turner & Townsend peer review estimate.

Turner & Townsend advises that, based on their research and experience of planning for light rail systems in Australia, the initial "draft cost estimate" WT Partnership provided is overly optimistic. It was recommended by Turner & Townsend that the draft estimate that they reviewed be examined in more detail and supported by more evidence-based data.

The methodology used by Turner & Townsend in carrying out the peer review was advised to be based on experience and benchmarking to other light rail systems they have judged to be similar. They also established the following key principles:

- **Escalation** – assumed to be 4th quarter 2014 and no provision for escalation from 1st quarter 2015 to commencement of revenue services.
- **Property acquisition** – Includes land acquisitions, relocations, alterations / refurbishments / demolitions and legal and other fees excluded from scope of their review thus used values used within the draft estimate.
- **Existing utilities** – Used an overall rate per km using based on 'similar' projects as well as experience in other light rail projects (utility costs presented as a % of light rail infrastructure and system total cost).
- **Trackform** – Overall rate per metre for trackform from other projects used and compared to draft estimate.
- **Rail alignment (structures)** – Rate per metre for elevated structure compared to other similar structures.
- **Stops** – Cost based on similar stops in Sydney light rail project and others globally.
- **Precincts** – Road works and footpath works between stops were assessed against typical % these works 'usually form as part of overall scope'.
- **Bulk and traction power** – Unit rates for supply and installation were applied to the element quantities of substations, overhead wiring, small power and lighting from their 'internal cost database'.
- **Rail systems** – Benchmarked rates from "internal cost database" for supply and installation of communication and security systems, tram and traffic control signalling, combined services route, passenger information systems and ticketing systems (applied to alignment length).
- **Depot and stabling** – Rates per facility/building, including fit out, and an operations control centre were compared to other similar projects on a total cost and cost per LRV basis.
- **Contractor's indirect costs** - The specific project requirement for preliminaries including the core management and site based teams, temporary construction facilities such as construction sites, office buildings and lay down areas, insurances, traffic management and main contractor's design costs were analysed as percentages of total direct construction cost and benchmarked against comparable projects.
- **Project / owner's costs** - Requirements for external appointments and internal costs calculated as a percentage of total construction costs and benchmarked against comparable projects
- **Risk and contingency** - Based on the information available upon which the estimate has been prepared, together with the assumptions made, direct costs, indirect costs, engineering, procurement and management, the adequacy of the total risk allowance as a percentage of the total cost was assessed and benchmarked against comparable projects.

The above methodology is a useful approach. However in IWA view, since all light rail systems are unique and have individual issues to be addressed, many resulting in material differences in cost, a more appropriate approach would be to carry out a detailed analysis of the alignment and thus have a more robust understanding and thus cost estimate. The WT Partnership appears to have taken this approach although the materiality of changes made to the version (2/12/2014) reviewed by Turner & Townsend and a subsequent version (22/12/2014) does raise questions.

The adjusted (22/12/14) WT Partnership cost estimate of $2,626m ($78.07m per route km) was much closer to the Turner & Townsend cost estimate of $3,305m ($98.25m per route km) and because the methodology followed was based on a detailed alignment assessment, in IWA view this is a more credible basis to establish a cost estimate to use at this stage of the project. Table 7.3 summarises the cost estimates per route km for both WT Partnership versions and the peer review cost estimate.

Table 7.3 CAPEX summary of estimates

	WT Partnership (2/12/14) model corrected	Turner & Townsend peer review	WT Partnership (22/12/14)
Project total CAPEX	$1,614m	$3,305m	$2,626m
Cost per Km (33.64k)	$47.97m	$98.25m	$78.07m

7.2 LRT design and construction cost comparisons (Australia)

IWA undertook high-level comparisons of the project team capex estimates with corresponding estimates for various recent and current Australian LRT systems. CAPEX costs were sourced relating to the Adelaide extension, Sydney extension, Sydney, Gold Coast Light Rail and ACT Light Rail systems. These indicate a CAPEX build cost per route (double track) km in the range A$66m to $100m (excluding vehicle CAPEX). Extensions were materially less and thus are excluded.

IWA notes that the ACT Light Rail is currently in the process of being tendered and whilst the Gold Coast Light Rail build has been competed it is understood within the industry that the D&C component was well over budget Recent Sydney Light Rail tender cost (accepted) also significantly exceeded the cost estimate developed by the project team. The above indicative costs incorporate estimated overrun costs.

These comparatives tend to suggest that the Turner & Townsend estimated cost is high whilst the WT Partnership ‘initial’ estimate was unrealistically low, but has subsequently been updated.

The cost estimate subsequently estimated by WT Partnership appears however to be a more credible benchmark ($78.07m per route km) and broadly comparable to the Australian benchmarks (inflated to reflect updated outcomes) although the impact on costs of a 100% “wire free” LRT system should be reviewed further in order to provide a more robust estimate.

IWA nonetheless considers that based on comparison to LRT systems within Australia that the WT Partnership adjusted cost estimate is broadly within IWA expectations.

7.3 Summary infrastructure capital findings

The methodology of WT Partnership and Turner & Townsend was different. The WT Partnership approach appeared to be based on a detailed assessment of the selected alignment whilst the Turner & Townsend methodology was based largely on benchmarking and drawing on information from within their “data base”. For a peer review process the peer review is a reasonable approach as was the WT Partnership approach for their purpose.

The level of contingency used in the CAPEX model initially by WT Partnership was 20%. Turner & Townsend used 30% (to be reduced as the design progresses). WT Partnership subsequently used 30% in their reworked cost estimate. IWA is of the view that contingency level at this stage should be larger and points out the recent Australian light rail projects where the cost materially exceeded the cost estimates and/or actual build costs. At this stage IWA are of the view that the 30% used by Turner & Townsend may be too low. IWA notes that other similar Light Rail projects at this stage of development provide a contingency of up to 40%.

The WT Partnership model is detailed with unit rates being applied for all works. IWA review of the detail did not identify any gap, but questions why overhead wire is required for depot operations whilst the total network otherwise is wire free.

Lack of a system scoping document and detailed assumptions by WT Partnership to support their CAPEX model is also a gap that would be very useful to reference. Adding a “tab” with detailed outline of the methodology they applied and assumptions would significantly improve this model.

The initial WT Partnership draft estimate was equivalent to $47.97m per route km, whilst the Turner & Townsend estimate was equivalent to $98.25m per route km. WT Partnership subsequently reviewed and adjusted their cost estimate to $78.07m per route km. This is a cost that, based on Australian examples, IWA considers to be a reasonable initial cost estimate. However, we caution that the lack of a detailed scope means that there is no assurance that WT Partnership accounted for all material items and issues within their model.

IWA also note that advice provided by Ken Davis (Title “Light Rail Power System”, dated 220/10/2014) advised that “in a hilly city such as Auckland, overhead line is likely to be the best or only solution in some places”. This limitation has not been addressed within material sighted.

IWA note a report by URS titled “Structural Review Light Rail Transit (LRT) Loadings/Specific Bridge Review” and note with the Grafton Bridge that “it is improbable that the bridge will be capable of being strengthened further to carry two LRT tracks”. Subsequently IWA is advised the solution proposed was that the central 120m of Grafton Bridge would be designed with a single track section (or interlaced gauntlet tracks) with traffic signal control. Therefore it would only have to support the dead weight of a single track slab, and the centre span of the bridge could only be ever occupied by one LRV at a time. Subsequent advice is that the intent is to use a single track only. The view expressed was that this should not create any difficulties operationally. IWA does not agree with this view in the absence of a more detailed assessment.