COOMA AND MONARO PROGRESS ASSOCIATION

CONCEPT PLAN FOR CANBERRA TO EDEN RAILWAY

PART 2 – PRELIMINARY ESTIMATE OF CONSTRUCTION COSTS

This document was prepared by Stormcloud Engineering on behalf of:
Cooma and Monaro Progress Association
PO Box 1239
Cooma, NSW, 2630

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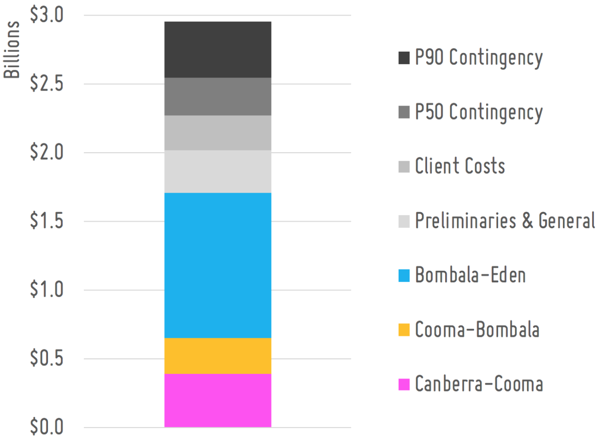
EXECUTIVE SUMMARY

This study presents a high-level estimate of construction quantities and costs for the proposed Canberra – Eden Railway, and is intended to inform the early, pre-feasibility planning stage. It should be read in conjunction with Part 1 of the study, which explores the concept plan and route options, published in June 2018.

The total project cost for the Canberra-Eden Railway, including direct construction costs, preliminaries & general, client costs and contingency, is estimated at **$2.95 billion** at a P90 contingency, or **$2.54 billion** at P50. Direct construction costs are **$1.71 billion**.



The cost data is sourced from a literature review covering both Australian data and comparable economies, however it relies significantly on two studies in particular: the Inland Rail Alignment Study (Parsons Brinckerhoff, 2010), and the High Speed Rail Study Phase 2 (AECOM, 2013), herein referred to as "IRAS 2010" and "HSR 2013". These are considered to be the most exhaustive studies into large-scale freight and high-speed passenger rail projects in Australia. Australian Rail Track Corporation data has also been used extensively. Design Standards are generally taken from the Inland Rail Working Paper No. 6 (2008), which itself adopts ARTC standards as the governing rail standard.[1]

All prices have been converted to 2018 AUD. Contemporary pricing in sources has been converted using the Reserve Bank of Australia's Consumer Price Index (CPI). An alternative inflation calculation was investigated, using the Australian Bureau of Statistics' Producer Price Index (Heavy and Civil Engineering), however the difference between the two indices was found to be negligible for the relevant time period (<1%). For simplicity, the CPI has been used throughout.

Where source documents are priced in international currency, prices have been converted into Australian Dollars using the average exchange rate for the year in question, and then converted to current-year dollars using the method above. Additionally, a multiplier is applied to take account of international differences in construction costs (for example, a 35% premium is applied to cost data sourced from the USA).[2]

In addition to the construction costs, allowance has been made for "soft costs", being inclusive of contingency (to account for uncertainty at the early planning stage), Preliminaries and General (contractor overheads and margin) and Client Costs (head-office costs, design and project management). While these additional costs have been based on contemporary Australian experience with large-scale civil infrastructure, they are presented separately to direct construction costs in order to allow consideration of how alternative contract arrangements may impact on total cost.

Although every effort has been made to ensure the accuracy and completeness of both the construction quantities and the cost estimates, the estimate is based on literature review rather than developed from first-principles building on detailed engineering design. In order to develop the Preliminary Estimate into a more rigorous Detailed Estimate, stakeholders should first refine the proposed corridor, and subsequently perform a detailed site survey including geotechnical analysis, heritage review, environmental impact assessment and community consultation.

Additional information about the methodology used to prepare this report can be found on the author's website: http://www.hotrails.net.

Edwin Michell
August 2018

TRACK

The Inland Rail Alignment Study (referred to herein as IRAS 2010) estimates $660,000 per kilometre for single-track greenfield construction ($765,000/km in 2018 AUD). This includes supply and stockpile of rail and sleepers, ballast supply and placement, and installation of rails. An earlier study by the Australian Rail Track Corporation (2001) estimated the replacement cost of track to be $455,000/km ($777,000 in 2018 dollars), while a repeated ARTC study in 2007 found $573,221/km ($725,000 in current dollars).[5] In each case the specifications of the track are as per Inland Rail's design standards for Class 1 track (25t axle load, 60kg/m rail, concrete sleepers at 600mm centres, 300mm ballast depth). These numbers all agree closely and can therefore be treated as high-confidence; we will conservatively use **$765,000/km**.

The cost for upgrade of Class 3 or lower track to Class 1 is slightly higher at **$835,000** in current dollars (IRAS 2010). The reason for the higher cost is the need to remove and restore the ballast and capping layer of the formation, as well as disposing of old sleepers. Removal of old rails is assumed to be cost-neutral on the basis of scrap value.

Upgrade cost for Class 2 track is much more affordable, however it is not relevant to this study as there is no existing Class 2 track in the Queanbeyan-Bombala Railway corridor.

The higher upgrade cost will apply to most of the Canberra-Cooma section as the track is still in place, however the greenfield cost will apply to the remaining sectors, as the track has already been removed in most of the Cooma-Bombala section, and the Bombala-Eden section is all greenfield.

• Greenfield Single Track:	$765,000	per kilometre	Source:	IRAS / ARTC
• Upgrade Existing Single Track:	$835,000	per kilometre		IRAS
• Tangential Turnouts (160km/h):	$1,000,000	each		IRAS
• Primary Turnouts (60km/h):	$310,000	each		ARTC 2007
• Diamond Crossings:	$115,000	each		IRAS

SIGNALLING

The Inland Rail study (2010) gave little consideration to signalling costs, and the numbers given in the High Speed Rail study (2013) are not applicable due to the much higher design speed. We therefore need to look elsewhere for our signalling estimates.

The 2007 ARTC study gives an average per-kilometre cost of signalling and communication infrastructure (ranging from about $70,000 to $120,000 per kilometer), however unit costs for individual hardware such as switches and points are not given. Ideally we want to find unit costs for all Centralised Traffic Control (CTC) hardware – lineside signals, turnout controls, active level crossing controls, communication and power mainline cabling.

The 2001 ARTC study gives a unit cost only "per loop", of about $1,400,000 in current dollars. This includes "6 signals, 4 track circuits, 2 interlocks, 2 point machines, local radio, telemetry, etc". We shall assume this can be taken to impute a cost of $700,000 per single-track control point. Similarly, IRAS 2010 costs passing loops at $5.75 million each — including 2km of track, 2 turnouts, plus associated signalling. Deducting the costs of track and turnouts, we are left with about $2.25 million, or $1.125 million per control point. This gets us close, but ideally we would prefer a more direct estimate of unit costs.

A 2011 study by the Minnesota Department of Transport[3] gives us just what we are looking for. That study investigated costs to establish mixed-use medium-speed rail services at speeds of 79-110mph (125-175km/h). Converted to 2018 AUD and applying a loading of 35% to account for Australian construction costs versus the USA, the unit costs are:

• Mainline CTC cabling and lineside signals:	$200,000	single track-km
• Control point for single-track turnout	$1,000,000	each
• Control point for double-track turnout	$2,000,000	each
• Control point at Universal Crossover:	$2,500,000	each
• Traffic signal pre-emption:	$115,000	each

These numbers agree well with the previous data, and appear plausible in an Australian context. For example, a 2011 study for the Port Waratah Coal Loop gave the unit cost of a single signal unit as $43,000, while communication cabling and power supply together came to about $185,000 per kilometre.[4] With the Minnesota data predicting $200,000 for cabling and general signals, this would imply a signal frequency of approximately 1 per 3 kilometres, which is plausible.

Additionally we will assume a nominal sum of $10,000,000 for fitout of a central control centre (as per IRAS 2010), assumed to be located at Hume Business Park, near the railway line in south-eastern Canberra.

EARTHWORKS

Bulk rates for earthworks are sourced from the High Speed Rail Study Phase II (Arup 2013). Different rates are given for rural and urban locations:

	Rural	Urban	
• Cut (rock)	\$ 29	\$ 61	/m^3
• Cut (non-rock)	\$ 10	\$ 18	/m^3
• Fill	\$ 12	\$ 23	/m^3
• Mass-haul	\$ 2	\$ 2	/m^3-km

The ARTC estimate (2001) is somewhat cheaper than the above, at \$17/m^3 for cut and \$9/m^3 for fill in present dollars. No distinction is made between rural/urban or rock/non-rock in the ARTC data. The figures for Inland Rail are broadly similar to HSR 2013, but much more detailed (ie, having a wider variety of rates for various geological ground types), and thus not as applicable to this study's level of detail. The HSR figures will be adopted as the more conservative estimate.

As a geological survey is beyond the scope of this Preliminary Estimate, we will take the average of the rock and non-rock values as indicative of the cost of a generic cut. Additionally, rather than calculate haulage individually for each cut, we will price-in 5km of haulage as part of the base cost of cut and fill (divided equally between cut and fill, as it is assumed all excavations will be balanced cut/fill). This will add \$5 to the volumetric cost of both cut and fill.

Rounded up to the nearest whole dollar, our bulk rates for earthworks are therefore:

	Rural	Urban	
• Cut (generic)	\$ 25	\$ 46	/m^3
• Fill	\$ 17	\$ 28	/m^3

Also, we will assume that volumes of cut and fill will be balanced overall (ie, no borrow or dump). We can therefore take the average of the rate for cut and fill, giving a generic "earthwork" cost of \$21/m^3 (\$37 urban). This is sufficient for a first-order approximation.

An accurate volumetric estimate of every cutting and embankment for a 300km+ railway is also beyond the scope of this study. Instead, an average per-kilometre rate will be calculated as a function of peak amplitude, on a kilometre-by-kilometre basis. Assuming a sinusoidal variation of average depth, and integrating over the length of a full balanced cut-and-fill, the average cross-sectional area can be approximated as about 64% of the peak cross-sectional area. This allows a relatively simple preliminary estimation of earthwork volume with a high degree of responsiveness to actual terrain characteristics of the chosen route, rather than just applying per-kilometre rates for terrain designated as "undulating", "mountainous", etc.

In calculating cross-sectional area, we assume a formation geometry complying with ARTC guidelines:

- Formation width 7m
- Gradient of batter slopes 1.5 to 1

Such specifications are conservative; it is highly likely that the gradient for cuttings through most types of rock can be much steeper (at least 1:1). Full details of volumetric estimation are available at **www.hotrails.net/earthworks.**

BRIDGES & VIADUCTS

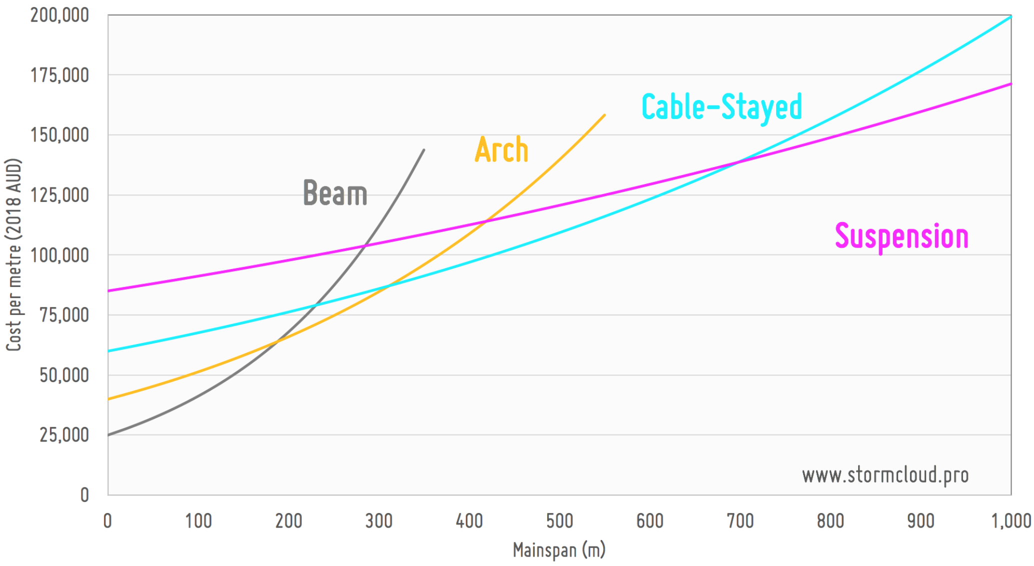
Estimates for bridge structures vary widely. The following figures are 2018 dollars per metre of structure:

- ARTC 2007 — $15,000 - $25,000 — 4-16m span, concrete deck, single track
- IRAS 2010 bridge — $29,000 - $63,000 — 18-25m span, single track over water
- IRAS 2010 viaduct — $19,000 - $21,000 — As above but over land, height 15-25m
- HSR 2013 — $118,000 — 50m span, box-girder, double-track

Additionally, due to the formidable terrain of the Bombala-Eden leg, several bridges with a mainspan significantly larger than the above estimates are required (100m+). Bridge expense becomes exponentially higher with increasing span, as the bending moment increases with the square of span. Construction expense can therefore be approximated by the equation **Cost = Ae^{BS}**, where S = mainspan in metres, e is the natural logarithmic base (Euler's Number, approx. 2.718), and A and B are empirically determined constants.

An 2014 empirical study by the author of the actual all-in cost of major bridges throughout the world determined the following values for A and B for various styles of bridge (adapted to 2018 AUD and with regional and load multipliers applied):

	A	B	Span range	Cost range (per metre)
Beam	25,000	0.0050	10 - 300m	$25,000 - $125,000
Arch	40,000	0.0025	100 -300m	$50,000 - $80,000
Cable-Stayed	60,000	0.0012	300 - 1000m+	$80,000 - $200,000+
Suspension	85,000	0.0007	750 - 2000m +	$150,000 - $300,000+



Very small streams, or shallow floodplains, usually require culverts instead of bridges. Again, the available cost estimates vary widely:

- ARTC 2001 — $2,500 — Rail Deck Culvert (per square metre)
- IRAS 2010 — $230,000 - $400,000 — Single to 7-cell 5.05x4.2m box culvert (unit rate)
- IRAS 2008 — $2,150,000 — Continuous 2.4x2.4m floodplain culverts (per km)
- HSR 2013 — $35,000,000 — Continuous box culverts (per km)

The HSR study is an outlier — having very basic box culverts costing more than viaducts or short-span bridges seems anomalous. Similarly, the IRAS 2008 rate of barely over $2m/km strikes the author as a little low — it would barely cover the cost of materials. Taking the 2001 ARTC square-metre rate and assuming a deck width of 2.4m to match the IRAS specifications, this would equate to a linear rate of **$6 million per kilometre.** This is a more plausible estimate, and will be adopted for this study.

TUNNELS

Tunnels are generally the most expensive single cost item on a per-metre basis (with the exception of very long-span bridges, of which none are anticipated for this project). Estimates in the literature vary widely, with recent estimates significantly higher than those from the 2000 decade or earlier. This may be at least partially explained by the recent trend for enhanced safety standards, among them the requirement for fully fire-separated emergency exits in tunnels above a certain length (usually 500 — 1000m), as well increased ventilation requirements.

It is also noted that tunneling cost is strongly dependent on the cross-sectional area, and that the costs for a single-track, single-stacked tunnel will therefore be lower than for dual-track, or tunnels suitable for double-stacked trains. The cross sections (and therefore costs) of high-speed tunnels are also inflated by aerodynamic requirements.

At least two new tunnels are proposed in the Bombala-Eden section, between 500m and 1000m in length for the preferred route (alternative routes may be possible with longer tunnels of up to 5km in length, however they are beyond the scope of this study). It is assumed, as per Inland Rail 2015, that the construction of tunnels up to 1000m in length will be by excavator, roadheader, or drill-and-blast. Construction by Tunnel Boring Machine (TBM) is not economic at short lengths. Additionally, it is assumed that fire-separated emergency exits will not be required for tunnels under 1000m in length.

TUNNEL COST ESTIMATES FROM RECENT AUSTRALIAN EXPERIENCE:

• ARTC (2001)	$18,880	(single track, single stack)
• NWRL (2013)[5]	$42,150	(dual-bore metro tunnel, per bore)
• ARTC (2007)[6]	$50,000	(single track, single stack)
• **WPI (2012)[7]**	**$67,500**	**(Australian average)**
• IRAS (WP3 2008)[8]	$68,580	(contemporary NSW and QLD tunnels)
• IRAS (2010)	$127,000	(single-track, double stack)
• HSR (2013)	$156,000	(dual-track, 400km/h)

The higher estimates — IRAS 2010 and HSR 2013 — are for tunnels with a much larger cross-sectional area than specified in this study, while the low estimate (ARTC 2001) was not based on actual contemporary projects, but rather an assumed "replacement value," which may not accurately reflect actual replacement cost. The median estimate (Worcester Polytechnic Institute, 2012) is considered the most applicable, as it is based on actual contemporary project estimates ranging widely in scope and size, and also matches well with a 2010 Infrastructure UK study into tunnel cost versus bore diameter.[9]

Most recently, the 2013 contract for the North West Rail Link tunnels was $1.15 billion for twin 15km tunnels,* coming to a linear rate of about $38,330 per bore-metre ($42,150 in 2018 dollars). While the lower rate is to be expected due to the tunnels' smaller diameter, economic TBM construction, and dual-bore configuration making emergency egress simple, it still suggests that the median estimate may in fact be conservative.

There is some evidence that shallow "cut-and-cover" type tunnels are cheaper to construct than an equivalent deep-bore type, typically by approximately 33%.

For existing tunnels, we will assume a refurbishment cost amounting to 30% of the typical lineal cost of a new tunnel.

This study will adopt the median estimate of $67,500 per metre. The costs presented for tunnels are "all-in" contract costs including preliminaries & general as well as all contractor overheads, and require no further loading.

* The $8bn project was completed in 2018, about $500 million under budget, so these numbers can be treated as high-confidence.

CIVIL WORKS

Civil works refers to ancillary works that are not part of the railway track itself, but are required to safely interact with existing infrastructure, urban development and the environment. In this study we will include roadworks, level crossings, grade separations, pedestrian crossings, fences, drainage, noise barriers, utilities relocation and demolition. Data has been sourced from a number of sources, as no single study was found to have a complete list of all necessary civil cost items that were appropriately specified for this railway (for example, many of the items in the 2013 HSR study were vastly overspecified for our purposes, due to that study's 400km/h design speed).

Roadworks

• Gravel Road	$50,000	lane-km	Source: BITRE 2018[10]
• Bitumen Road (local)	$250,000	lane-km	BITRE 2018
• Bitumen Road (highway)	$750,000	lane-km	BITRE 2018

Fencing / Barriers

• Agricultural wire fence	$20,000	linear km	ARTC 2007
• Chainlink "Cyclone" fence	$50,000	linear km	Michell 2014
• Steel palisade fence	$100,000	linear km	HSR 2013
• Concrete barrier	$350,000	linear km	Michell 2014
• Retaining Wall	$2,500	square metre	HSR 2013
• Noise attenuation wall (rural)	$5,000,000	linear km	HSR 2013
• Noise attenuation wall (urban)	$10,000,000	linear km	HSR 2013

Crossings

• Passive farm crossing (signs only)	$25,000	each	ARTC 2007
▫ Farm roads, tracks, private driveways			
• Passive level crossing (signs only)	$120,000	each	ARTC 2007
▫ Unsealed public roads			
• Active level crossing (lighted)	$350,000	each	MNDoT 2011
▫ Minor sealed roads			
• Active level crossing (gated)	$1,000,000	each	MNDoT 2011
▫ Major (non-highway) local roads			
• Livestock underpass	$150,000	each	The Land 2018[11]
▫ Small underpass similar to a culvert, allowing passage to livestock and small vehicles.			
• Minor under- or overpass	$500,000	each	IRAS 2008
▫ Single lane crossing, must be constructed in an embankment or cutting of sufficient depth			
• Minor grade separation	$5,000,000	each	IRAS 2010
▫ 2 lane overbridge with 300m approach embankments both ends			
• Major grade separation	$6,000,000	each	IRAS 2010
▫ 4 lane overbridge with 300m approach embankments both ends			
• Pedestrian overpass	$1,000,000	each	Michell 2014

Drainage

• Cross-drainage	$80,000	route-km	MNDoT 2011
• Culvert (single cell)	$250,000	each	IRAS 2010
• Culvert (multi-cell)	$350,000	each	IRAS 2010

Utilities Relocation

▫ Rural areas	$125,000	route-km	HSR 201
▫ Urban areas	$575,000	route-km	HSR 2013
▫ Site clearance / Minor demolition	$135,000	route-km	HSR 2013

LAND ACQUISITION

Land acquisition isn't as simple as just working out the value of the land. It generally will include the following:

- The market value of the land acquired
- A compensatory uplift for disruption
- Environmental offsets if applicable
- Legal and other overheads (including the cost of any challenges to acquisition)

Hard data on the actual, all-in costs of compulsory land acquisition is surprisingly hard to find. IRAS 2010 estimated that the average cost of land acquisition (including all of the above) would total approximately $100,000/ha, or $400,000/km for a typical 40m wide corridor. However simply applying this cost to all sections of the railway requiring land acquisition is inappropriate, especially since many of the acquisitions will be for only minor changes to the existing corridor, while others will be for an entirely new corridor with various levels of disruption to landowners. We will estimate the acquisition cost based on reasonable assumptions about land value, compensation, and legal overheads.

According to the 2017 Australian Farmland Values report, the median cost of farmland in South-East NSW was $5,489/ha in 2017 (Rural Bank 2018).[12] Specifically for the LGAs that the railway will pass through, the values are:

- Queanbeyan-Palerang $5,390/ha
- Snowy-Monaro $2,299/ha
- Bega Valley $7,129/ha

The report also indicates a typical variation by size of blocks. Small blocks (30-99ha) traded at a premium of almost 100% to the overall median, 100-299ha holdings traded at approximately the overall median, holdings of 300-499 traded at a discount of approximately 40%, while holdings above 500ha traded at a discount of almost 60%.

According to IRAS Working Paper No. 8 (ARTC 2008), compensation for disruption is generally up to 200% of the pre-acquisition value, and rarely up to 400%.[13] This implies that even with high levels of compensation, a majority of land acquisition cost is in legal costs and other overheads. Given that land values along the proposed Inland Rail corridor are comparable to those for the Canberra-Eden railway, applying a general premium for legal and other overheads of $200,000 per kilometre of corridor acquisition broadly replicates the overall average cost in IRAS 2010.

For crown land (which comprises much of the proposed route), we will assume negligible cost of the land itself (already being owned by the state), as well a 50% discount to overheads due to less onerous legal issues (fewer counterparties, larger blocks of land, no compensation issues, etc). This is considered conservative and the true cost of acquiring crown land may well be far lower than this. The exception to this is corridor in National Park, which will be assigned a land value equal to the typical land value of neighboring farmland, due to the requirement to purchase environmental offsets for any area of alienated national park. It will be assumed that such offsets will be conducted on the open market, and therefore will be assigned a compensation factor of 1 (ie, no compensation over and above land value).

We will adopt following costs for various corridor classes, and compensation factors for level of disruption.

Land Class	Base acquisition value ($/ha)
Crown Land	$0
Large Holding (>500ha)	$3,000
Medium Holding (300-500ha)	$6,000
Small Holding (30-300ha)	$12,000
Hobby Block (1-30ha)	$24,000
Township Block (<1ha)	$200,000

Corridor Type	Compensation Factor
Corridor moved <100m	2
Corridor moved >100m, <500m	3
New corridor, low disruption	4
New corridor, high disruption	5

STATIONS

The cost of stations, including freight facilities, is highly dependent upon the specific details of each site. For this study, we propose the refurbishment of existing heritage stations where practical to do so, and where no structure presently exists, the construction of new, modern facilities commensurate with the expected level of passenger and freight demand. We will base construction cost estimates on empirical evidence from contemporary station projects in Australia. Major stations range from $20-80 million (eg Wayville SA, Williams Landing VIC, HSR 2013 study), minor stations are generally well under $10 million (eg Oaklands SA), while renovations of existing stations are $1-3 million (eg Ballarat VIC). We will conservatively adopt the following assumed costs:

• Major station	$25 million	each	Source:	Michell 2015
• Minor station	$7.5 million	each		Michell 2015
• Rebuild existing	$2 million	each		Michell 2015
• Refurbish existing	$1 million	each		Michell 2015
• Car parking (at grade)	$7,000	per space		HSR 2013
• Multi-level car park	$26,000	per space		HSR 2013

FREIGHT TERMINALS

Freight Terminal Costs are sourced from a 2018 study by Weigmans & Behdani.[14] The European data has been converted to Australian dollars at an exchange rate of AUD/EUR = 0.65. Note: Facility container capacity is given in annual TEU, "Twenty-foot Equivalent Units," ie, a standard 20-foot container.

The size of freight trains is highly variable, and therefore so is the typical capacity of container handling facilities. We can look at some typical numbers to give an idea of facility scale. A typical TEU weighs between 10 tons (IRAS reference train) and 15 tons (Weigmans & Behdani). The Inland Rail "Reference Train" is much larger than typical European or suburban trains — specified to the maximum length permitted on the ARTC Network of 1800m. The reference train carries 292 TEU, double-stacked for 40% of its length. In contrast, the Canberra Eden Railway will be single-stacked with a maximum length of 1200m (restricted by station precinct lengths in Cooma and Bombala), implying a maximum train capacity of about 175 TEU and 2,550 gross tons.

For comparison, Port Botany presently handles somewhat over 400,000 TEU, at an average train size of 99 TEU per train (substantially larger than the European average of 75). On average, each train trip replaced 49 truck trips. This is mainly for metropolitan trains, transferring freight between the Chullora yards in Sydney's inner west and Port Botany — the quantity of truck-km saved would be much larger for regional trains transferring freight across much larger distances.[15]

Type	Container Capacity (TEU/annum)	Trains Per Week (100 TEU/Train)	Infrastructure	Terminal Area	Capital Cost (2018 Million AUD)
Extra Large	500,000	100	12 tracks	40 ha	212
Large	100,000	20	6 tracks	10 ha	72
Medium	30,000	6	3 tracks	6 ha	15
Small 2	20,000	4	2 tracks	4 ha	8.5
Small 1	10,000	2	1 track	4 ha	5

* Interestingly, note that the typical container density per length of train is 15.5 TEU per 100m for single stacking, but just 19 TEU per 100m for double-stacking.

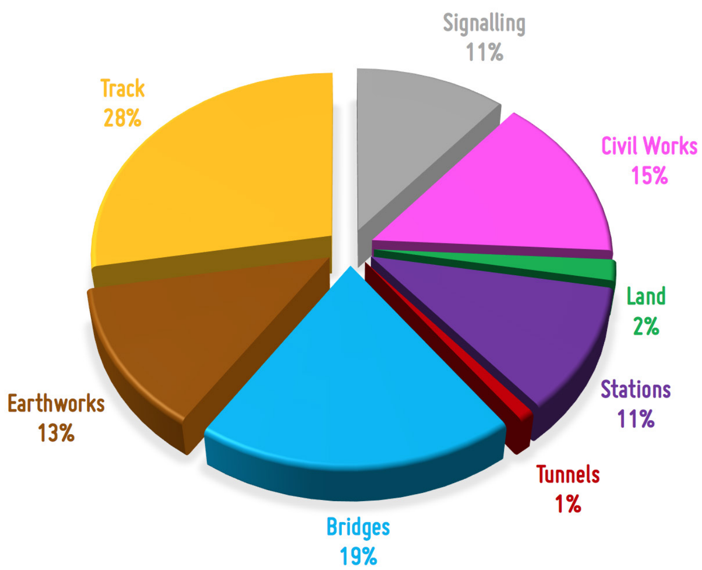
CANBERRA TO COOMA

Direct construction costs for the 114km Canberra to Cooma section total **$386 million**. The section utilizes the existing corridor for almost its entire length. The exceptions to this are:

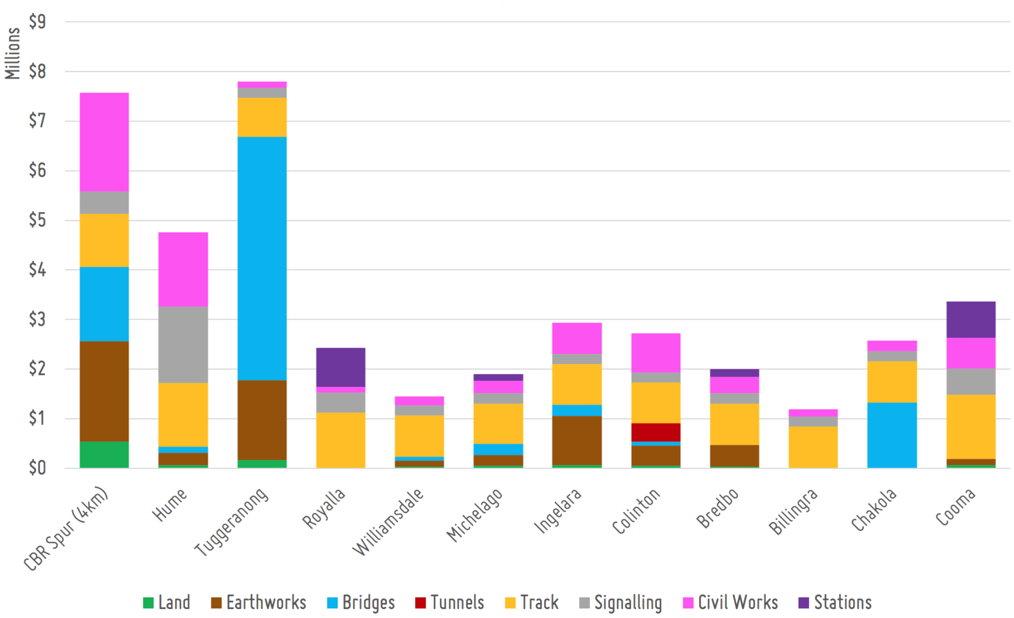
- A $71m, 5km spur line from HMAS Harman to Canberra Airport, including a $25 million terminal station
- A significant 1400m viaduct at Tuggeranong, to bypass a long section of tight curvature
- Earthworks at Michelago, Ingelara, Colinton and north of Cooma, to ease curvature.

In addition, 8 major bridges are to be replaced with new structures, including the 390m Numeralla Bridge near Chakola, as well as 3 new grade separations on the Monaro Highway.

Cost breakdown of Canberra-Cooma section



Cost per kilometre of Canberra-Cooma section in 10km lots (except as noted) *



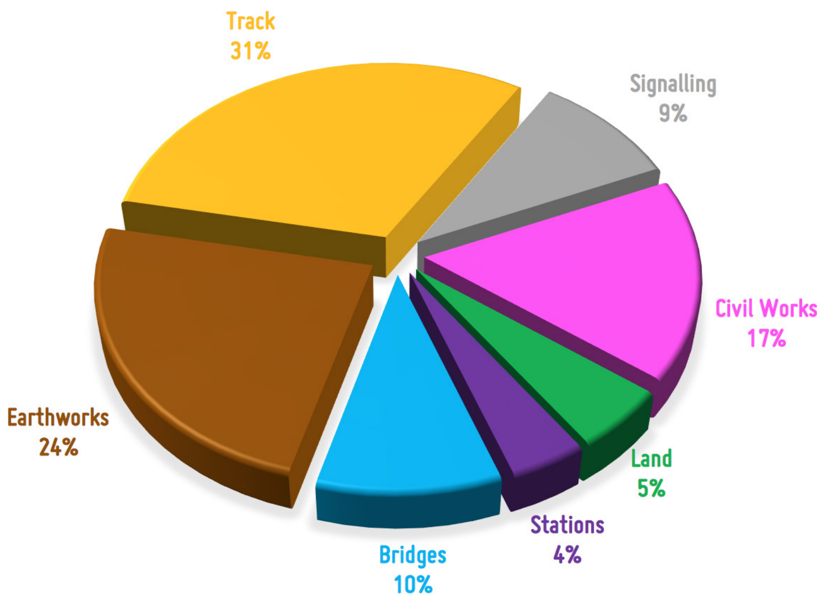
* Excluding cost of Canberra Airport station

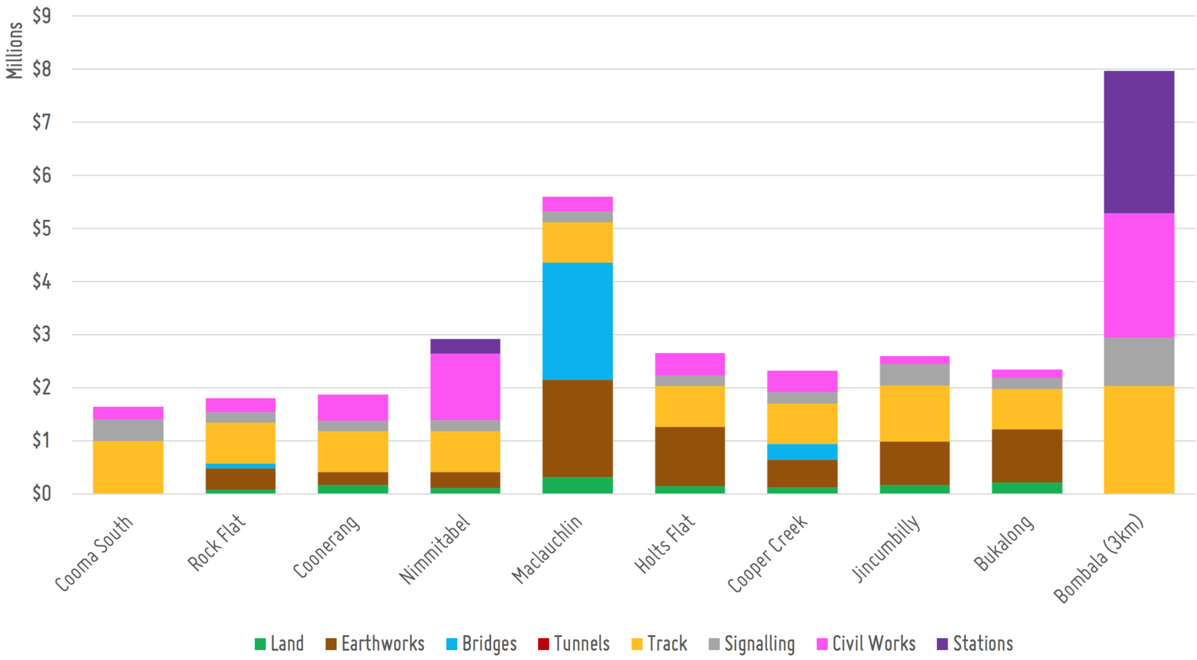
CANBERRA TO COOMA (114km)		$386 million $3.39 million per kilometre Including $71 million for Canberra Airport Spur
Description	**Quantity**	**Cost**
Land		
Mostly minor deviations to existing corridor with minimal disruption.	20km of new corridor 81 ha	**$7,109,000** ($87,680/ha)
Earthworks		
Most of the major earthworks are in the new works approaching the Tuggeranong Viaduct, or the new spur line to the airport. The earthworks for the 5 instances of curve easing are mostly small to moderate in amplitude.	0-5m peak 6km 5-10m peak 8km 10-15m peak 4km 15-20m peak 1km **Total volume 2,146,000 m3**	**$45,074,000**
Bridges		
2 new bridges (Molonglo and Tuggeranong) 8 existing bridges replaced 960m of replaced bridges	1550m of new bridges 960m of replaced bridges	$55,100,000 $26,248,000 **Total: $81,354,000**
Tunnels		
Refurbish existing Colinton Tunnel	160m	**$3,400,000**
Track		
Upgrade existing track to Class 1C and interface with existing rail corridor at Queanbeyan/ Fyshwick. 4km spur-line to Canberra Airport 1 major and 5 minor deviations	22.25km greenfield track 97km of upgraded track 9 turnouts	**$107,016,000**
Signalling		
Install new signalling along corridor Control centre near Canberra Terminus (nominally located at Hume Business Park)	114km CTC mainline 9 turnouts 5 crossing pre-emptions	**$43,007,000** Inc. $10m for control centre
Civil Works		
Roads: 78km maintenance track, 1km gravel road deviation, 2km local road deviation Crossings: 7 farm crossings, 5 passive LCs, 3 lighted LCs, 2 gated LCs, 5 minor grade separations, 3 two-lane grade separations, 2 four-lane grade separations Barriers: 165km agricultural fence, 44km chainlink fence, 10km security fence, 3km concrete barrier Utilities: 12km cross-drainage, 12 single-cell culverts, 2 multi-cell culverts, 4km urban utility relocation, 11km minor demolition, 5 major demolitions		Roads: $4,450,000 Crossings: $34,325,000 Barriers: $7,550,000 Utilities: $10,835,000 **Total: $57,160,000**
Stations		
Canberra Airport — Major station Royalla — Minor station Michelago — Refurbish existing Bredbo — Refurbish existing Cooma — Refurbish existing	5 stations 290 parking spaces (not including existing parking at Canberra Airport) 2 intermodal facilities (10,000 TEU/annum)	**$42,030,000**

COOMA TO BOMBALA

Direct construction costs for the 93km Cooma to Bombala section total **$262 million**. Major works include:

- Two significant deviations at Maclauchlin and Holts Flat in order to bypass excessive curvature. Maclauchlin deviation requires two viaducts totalling 1100m in length.
- Between Jincumbilly and Bombala, the corridor needs significant lengths of curvature easing. However the deviation from existing corridor is generally under 100m, reducing the amount of compensation required for acquisition of land.
- 3 major bridges to be replaced with concrete structures, including 500m of floodplain culverts
- 3 new grade separations on the Monaro Highway





COOMA TO BOMBALA (93km)

$261 million

$2.81 million per kilometre

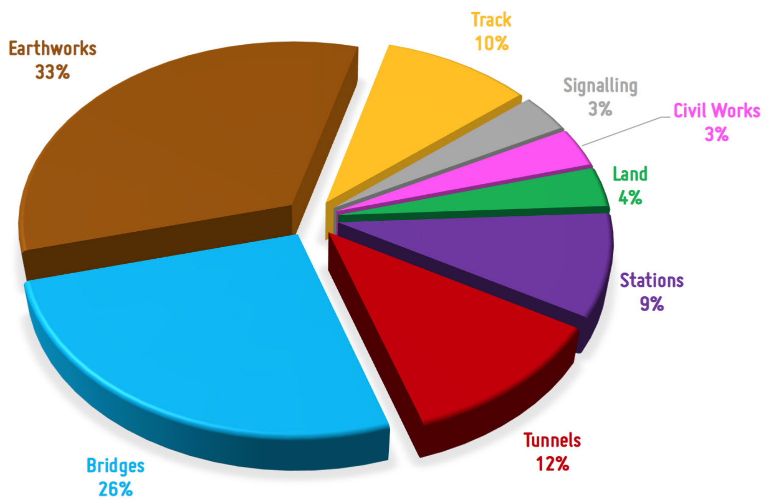
Description	Quantity	Cost
Land		
Significant lengths of minor deviation (corridor moved <100m), especially after Jincumbilly.	44km of new corridor 175 ha	**$13,534,000** ($77,531/ha)
Earthworks		
Only minor earthworks are required until south of Nimmitabel. The Maclauchlin, Holts Flat, Jincumbilly and Bukalong deviations all require moderate earthworks, though no single cut or fill exceeds 15m in amplitude.	0-5m peak 31km 5-10m peak 7km 10-15m peak 11km 15-20m peak 0km Total volume 2,958,000 m3	**$62,121,000**
Bridges		
2 new viaducts at the Maclauchlin Deviation 1 existing bridge replaced 2 existing bridges replaced with floodplain culverts	1100m viaducts 30m bridges 500m culverts	**$25,900,000**
Tunnels		
None	N/A	N/A
Track		
Upgrade existing track to Class 1C where track remains. Balance is greenfield at numerous deviations, as well as on existing formation where track has been removed.	90.25km greenfield track 6.25km of upgraded track 6 turnouts	**$80,260,000**
Signalling		
Install new signalling hardware along corridor, and at turnouts and active level crossings.	93km CTC mainline 6 turnouts 3 crossing pre-emptions	**$25,131,000**
Civil Works		
Roads: 72km maintenance track, 4km gravel road, 1ln-km local road, 750m highway Crossings: 11 farm crossings, 4 passive LCs, 1 lighted LCs, 2 gated LCs, 4 minor grade separations, 3 two-lane grade separations. Barriers: 172km agricultural fence, 9.5km chainlink fence, 4km security fence, 500m concrete barrier, 500m2 retaining wall Utilities: 12km cross-drainage, 12 single-cell culverts, 2 multi-cell culverts, 4km urban utility relocation, 11km minor demolition, 5 major demolitions		Roads: $4,613,000 Crossings: $20,105,000 Barriers: $5,740,000 Utilities: $13,205,000 **Total: $43,663,000**
Stations		
Nimmitabel — Minor station Bombala — Rebuild existing Potential for freight sidings at Jincumbilly and Bukalong (not costed)	2 stations 300 parking spaces 1 intermodal facility at Bombala (10,000 TEU/annum)	**$11,100,000**

BOMBALA TO EDEN

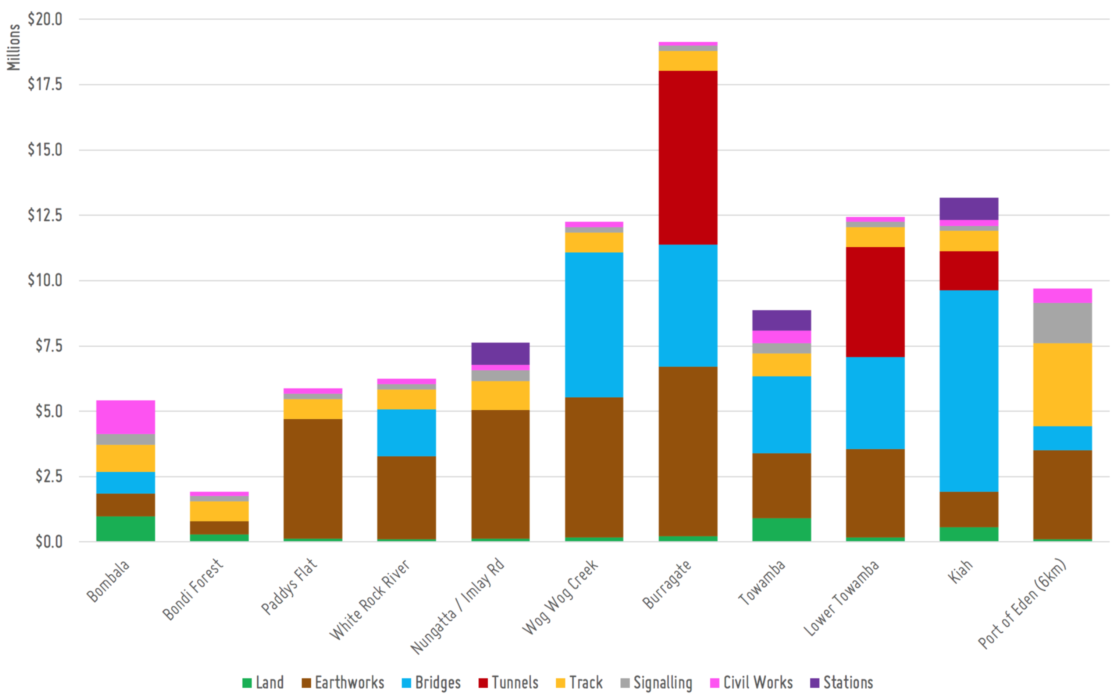
Direct construction costs for the 106km Bombala to Eden section total **$1.06 billion**. The engineering challenge posed by the descent of the South Coast Range is significant, but by no means unprecedented in Australia. The most notable works are:

- Extensive sections requiring deep cuttings and embankments up to 25m in amplitude;
- Numerous bridges and viaducts where the magnitude of earthworks would be too great, or undesirable on environmental grounds;
- Several major long-span bridges (>50m mainspan), including a signature 740m cable-stayed bridge over the Towamba River estuary near Kiah, having a mainspan of 250m
- Two major tunnels at Mataganah Fire Trail (950m) and Lower Towamba (600m)

Cost breakdown of Bombala-Eden section



Cost per kilometre of Bombala-Eden section in 10km lots (except as noted) *



* Excluding cost of the intermodal freight handling facility at the Port of Eden

BOMBALA TO EDEN (106km)		**$1.06 BILLION** $10.0 million per kilometre
Description	**Quantity**	**Cost**
Land		
Entirely new corridor (36km or 34% in National Park)	106km of new corridor 423 ha	**$37,348,000** ($88,335/ha)
Earthworks		
After the escarpment, numerous cuttings and embankments of significant amplitude are required. In some instances it may be economic to replace with additional viaducts, depending on geology.	0-5m peak 33km 5-10m peak 21km 10-15m peak 26km 15-20m peak 20km 20-25m peak 6km **Total volume 16,667,000 m3**	**$350,012,000**
Bridges		
6 new bridges (mainspan ranging from 25-125m) 13 new viaducts (typical mainspan 20m) 1 signature cable-stayed bridge over Towamba estuary (mainspan 250m)	3,355m of new bridges 5,400m of new viaducts 740m signature bridge	$101,188,000 $124,000,000 $60,000,000 **Total: $285,121,000**
Tunnels		
Two single-stacked tunnels constructed by roadheader, plus one cut-and-cover tunnel to underpass Princes Hwy	1,550m roadheader tunnel 200m cut-and-cover	**$118,500,000**
Track		
All-new greenfield track including associated sidings and passing loops	119km greenfield track 14 turnouts	**$105,035,000**
Signalling		
Install new signalling along corridor	106km CTC mainline 4 turnouts 1 crossing pre-emption	**$35,527,000**
Civil Works		
Roads: 3km gravel road deviation, 1km highway deviation **Crossings:** 1 farm crossing, 6 passive LCs, 1 lighted LCs, 2 gated LCs, 7 minor grade separations, 2 two-lane grade separations, 1 pedestrian overpass **Barriers:** 67km agricultural fence, 17km chainlink fence, 10km security fence, 3km concrete barrier **Utilities:** 85km cross-drainage, 3 single-cell culverts, 1 multi-cell culverts, 2km urban & 4km rual utility relocation, 63km site clearance & minor demolition		Roads: $900,000 Crossings: $15,595,000 Barriers: $2,190,000 Utilities: $17,675,000 **Total: $36,360,000**
Stations		
Nungatta — Forestry freight station and passing loop Towamba — Minor station and passing loop Boydtown Junction — Passenger station serving Eden Port of Eden — Major intermodal and bulk freight facility	4 stations 350 parking spaces 2 intermodal facilities (20,000 & 100,000 TEU/annum each)	**$96,900,000**

ESTIMATE BENCHMARKING

The results of this study can be compared to other major projects to validate the estimate, as well as to show the comparative scale of the Canberra-Eden railway compared to contemporary major civil engineering projects in Australia. Of these, the most directly comparable is Inland Rail.

The direct construction costs per kilometre of the Inland Rail project come to a bit over $4 million per kilometre averaged over the entire 1700km route, including 1100km of upgraded existing track and 600km of all-new track, through a variety of terrain types (this number rises to $6m/km once contingency and soft costs are considered). By comparison, this study finds the following costs:

- Canberra-Cooma **$3.39 million/km** Rural/suburban with mostly existing track, undulating terrain
- Cooma-Bombala **$2.81 million/km** Rural with a mix of existing and new track, undulating terrain
- Bombala-Eden **$10.0 million/km** Rural with all-new track, mountainous terrain, water crossings

This matches closely with what we would expect from the Inland Rail experience. When we look at the individual sections of Inland Rail, we find numbers similar to Canberra-Eden. For example, Bombala-Eden is comparable to Grandchester-Kagaru ($9.2 million/km), while Canberra-Bombala is comparable to Camurra to Inglewood ($2.5 million/km).

Perhaps the most significant component to benchmark is the earthwork package. As the single largest cost component of the entire railway, it is important to have plausible numbers. This study's results are compared to selected sections of Inland Rail in the table below. While the earthwork quantities for Canberra-Eden are certainly of significant scale, they are directly comparable to various sections of Inland Rail, as well as other contemporary large-scale civil engineering projects (for example, the 27km Woolgoolga to Wells Crossing section of the Pacific Highway duplication project has over 4,000,000m^3 of earthwork, coming to 149,000m^3/km).[16]

Canberra-Eden		Inland Rail	
Canberra-Cooma (114km)	2.2 million m^3 19,000 m^3/km	Inglewood-Oakley (144km)	2.3 million m^3 16,000 m^3/km
Cooma-Bombala (93km)	2.9 million m^3 32,000 m3/km	Toowomba Tunnel to Grandchester (71.8km)	3.1 million m3 42,000 m^3/km
Bombala-Eden (106km)	16.7 million m^3 157,000 m^3/km	Wellcamp-Charlton alternative route (168km)	19.6 million m^3 117,000m^3/km

COMPARATIVE ESTIMATE (AFTER VON BROWN)

Jeffry von Brown (Iowa State University, 2011) in "A planning methodology for railway construction cost estimation in North America" presents a general estimate of railway cost construction, allowing for factors such as land use, terrain and design speed.[17] We can use this to find a comparative estimate of the cost of the Bombala-Eden section.

For rural, mountainous terrain, a design speed of 110mph, and converted to 2018 AUD per kilometre, von Brown's cost estimates for single track come to $7,214,000/km. Multiplied by 106km for the Bombala-Eden leg, and by 1.35 to account for the generally higher construction costs prevailing in Australia, the von Brown comparative estimate comes to $1.019 billion, a difference of under 4% compared to the $1.06 billion in direct construction costs of this study.

While such close agreement at this stage of project estimation can surely be put down mostly to coincidence, it does lend additional support to the reliability of the Preliminary Estimate.

* Hard to believe now, but AUD/USD was 1.05 or higher throughout most of 2011.

SOFT COSTS

So-called "soft costs" over and above direct construction costs include:

- Contingency
- Preliminaries and general
- Client costs

Each of the additional costs have been estimated on a deterministic basis as a percentage of total construction costs, based on contemporary experience in New South Wales rail projects and other applicable sources. All soft costs are based on the total direct construction cost except as otherwise noted. Escalation (increase in project expense due to CPI inflation over the course of project delivery) is not included; all costs are to be read as 2018 Australian Dollars.

CONTINGENCY

Contingency is intended to account for project risk. Benchmark contingency figures cover an incredibly wide range, from around 5% to over 100%, though 25-35% is typical for a high-level estimate. It is considered good practice to use at least a P80 contingency (ie, an amount for which there is an 80% probability that construction costs will not exceed) at the early project stage. It is also logical that a higher contingency should be allocated to projects with higher inherent uncertainty.

Each section of the proposed railway is different in this regard — the Canberra-Cooma section is largely a rebuilding of the existing alignment, the Cooma-Bombala section involves significant deviations but still broadly follows the existing corridor, while the Bombala-Eden section is a significant new alignment through formidable country and involving multiple stakeholders.

This study will use the South Australian Government's "Estimating Manual for Road and Rail Projects"[18] to select an appropriate contingency percentage for the current project stage. This tool nominates a "Base contingency" percentage which is then modified up or down based on specific risk elements applicable to the project. This allows us to nominate an appropriate contingency for the three different sections of railway, based on the inherent differences between the three projects. The nominated contingency factors for each of the three sections are as follows (rounded to the nearest whole percent):

Section	Base Cost	P90 Contingency	P50 Contingency
Canberra-Cooma	$386 million	21% ($81.1 million)	8% ($32.5 million)
Cooma-Bombala	$261 million	34% ($88.9 million)	14% ($35.5 million)
Bombala-Eden	$1,060 million	48% ($508.9 million)	19% ($203.5 million)

Total contingency for the entire railway therefore comes to **$679 million (40%)** for P90 contingency, or **$272 million (16%)** for P50.

It should be noted that contingency in the context above is primarily used by government departments in order to allocate budgets to projects - it is not necessarily representative of actual expected construction costs. This study has elected to apply a contingency sum in line with what would be expected for a government-sponsored project at an early planning stage; the sum would be expected to reduce as planning progresses and a more refined estimate is produced. The amount of contingency to include in the Preliminary Estimate is ultimately a matter of judgement.

SOFT COSTS (cont.)

PRELIMINARIES & GENERAL

This is a measure of contractor costs over and above direct construction costs. It is typically taken to include contractor supervision, site establishment and maintenance, insurance, design, weather/delays, and contractor margin/profit. Based on the literature review, a figure of 20% would represent a conservative, mid-range estimate.

- IRAS 2008 — 21.5%
- MNDoT — 24%
- WPI 2012 — Range from 16-28% (data for different types of tunnels)
- Turner &Townsend 2017[19] — Range from 14.5% (Perth) to 18.5% (Sydney)

Land acquisition is excluded from the base cost, as it is not a direct construction cost. Note also that as our preliminary estimate for tunnel expense explicitly includes preliminaries and general, tunnel costs are also excluded from the base cost. The total P&G sum for the Canberra-Eden railway is therefore **$305 million**.

Section	Percentage	Base Cost	P&G Sum
Canberra-Cooma	20%	$379,331,000	$75,866,000
Cooma-Bombala	20%	$247,824,000	$49,565,000
Bombala-Eden	20%	$899,291,000	$179,858,000

CLIENT COSTS

The average client cost for rail projects in NSW, as a percentage of total construction cost, was estimated at 14% by a state parliamentary committee in 2012.[20] The wider Australian average was 16% in the same study. IRAS 2008 estimated 13%, while HSR 2013 estimated 11.5%. These estimates cover a relatively narrow band; this study will conservatively estimate 15% for all sections.

The client costs are therefore estimated at **$256 million** over the entire project**.**

SOFT COST SUMMARY

In total, the soft costs for the project come to $833 million (with P50 contingency) or $1,240 million (with P90 contingency), bringing the total project cost to **$2.54 billion** (P50), or **$2.95 billion** (P90).

The proportion of total project cost represented by soft costs is 28% at P50 contingency, and 42% at P90.

MONARO RAIL TRAIL

There is substantial support in the local community and associated councils for the Monaro Rail Trail, a proposal to turn the disused rail corridor between Queanbeyan and Bombala into a mixed-use trail primarily for cycling, but also for pedestrian and potentially equestrian use. Returning the corridor to active rail use does not preclude its use in tandem as a rail trail; the so-called "rails with trails" concept is widespread overseas (especially in the USA and UK) and could be applied to the Queanbeyan-Bombala railway with minimal difficulty. Some useful guidelines are published by the United States Department of Transport.[21]

In the development of the Concept Plan, the cost of a compacted gravel maintenance track that could serve also as a cycle trail has been included in the estimate (approx. 150km at $50,000 per kilometre). This track is to be located alongside railway embankments between Queanbeyan and Bombala, with low-level crossings across watercourses, or diversions to nearby road bridges. At cuttings and tunnels, the track will be on the existing land surface, nearby to the railway. The estimate for this track was made without detailed measurements and includes provisional sums only, over and above the cost of the railway, for works and land acquisition.

Issues to be addressed with rail trail co-location include:

- **Corridor width –** The corridor width of 40m is generally sufficient to accommodate a maintenance track / bike trail alongside, in fact in several areas there already is such a track (albeit requiring maintenance) — for example the Old Monaro Highway between Tuggeranong and Michelago.

- **Formation width —** The existing formation is not generally wide enough to accommodate the access track directly alongside the rail track (this would be undesirable from a safety perspective in any case). Therefore the access track will need to deviate around cuttings or embankments, or have these features widened.

- **Use of Deviations —** Where the upgraded railway deviates from the existing corridor, the remaining corridor will be available for exclusive use by the Rail Trail. There are several areas where this would be possible including Tuggeranong, Michelago, Colinton and Bredbo.

- **Pedestrian segregation —** The close proximity of rail vehicles at high speed (115-160km/h) will necessitate a physical barrier to ensure safety of trail users; it is proposed that a 180cm cyclone fence between the trail and the rail track would achieve this.

- **Suitability of existing structures —** Most existing timber bridges on the route are in poor condition, and unlikely to be safe even for foot traffic without substantial restoration cost; recent experience with timber bridge restoration in the ACT and Palerang region suggests such cost would be prohibitive. It is therefore not disadvantageous to the rail trail proposal for new bridges to be built for railway use; in fact it is highly likely to be advantageous, as such structures could be designed to include a cycleway at modest marginal cost.

The following are ballpark cost estimates for a Monaro "Rail with Trail", based on the Upper Hunter Rail Trail study.[22]

• 180mm exclusion cyclone fence:	150km @ $50,000/km	$7.5 million
• Bridges, extra over for cycleway:	1,490m @ $3,000/m	$4.5 million
• Underpasses for cycleway:	10 @ $50,000 each	$0.5 million
• Earthworks, extra over:	$6m^2$ * 25km @ $16/m^3$	$2.4 million
• Land, extra over:	5km @ $200,000/km (20m corridor)	$1.0 million

It is recommended that in the preparation of a feasibility study for the Monaro Rail Trail, the proponents give consideration to the railway returning to active use.

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For enquiries regarding the use of this work, please contact Edwin Michell at:

Stormcloud Engineering
PO Box 138
Bungendore NSW 2621
edwin@stormcloud.pro
ph. 0409 092 529