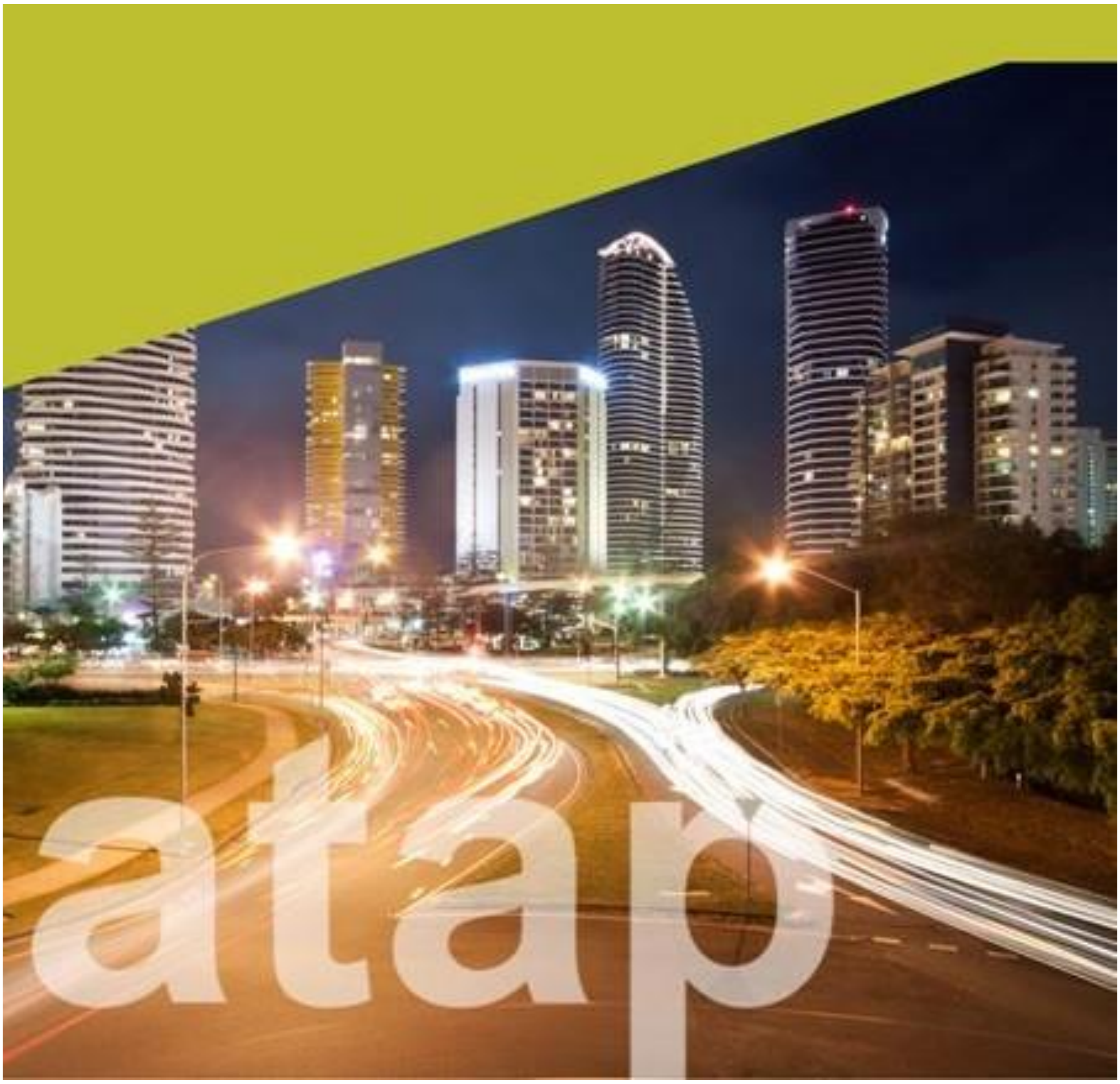
INFRASTRUCTURE AND
TRANSPORT MINISTERS

Australian Transport Assessment and Planning Guidelines

Worked Example: W3 Freight Rail
3.2 An upgraded regional branchline

August 2021



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1. Problem description

In recent years, there has been a substantial mode shift in rural freight movements from rail to road for many commodities. Over a long period, this process has been accelerated by significant investment in road network improvements and truck technology with very little improvement to the rail infrastructure and operation. But over time this freight transfer, which is mostly conveyed on heavy vehicles, has resulted in increased deterioration of some rural roads which are used by all motorists while there is considerable underutilisation of the rail asset which is often parallel or adjacent to the road corridor.

Upgrading rail corridors will assist in arresting the decline in rail mode share by offering an improved price-service package. This can be achieved in several ways:

- Heavier rail, sleepers, deeper ballast, improved signalling etc. in selected areas will allow higher capacity locomotives and wagons that will improve train operating cost.
- Improved infrastructure will improve productivity and efficiency and provide capacity for future growth if required.
- Improved alignment will give better train operating performance potentially improving transit times, reducing damage or product deterioration and improving service quality.
- Reducing double handling by eliminating mid-point transhipping.

Transfer of freight back to rail will ease pressure on the road system and potentially reduce maintenance costs.

For this worked example, it is assumed the existing branchline railway is about 100km in length to the nearest hub/junction. To illustrate the mode shift effect, it is assumed a parallel road is adjacent to the rail corridor and is of similar length. The main commodity is assumed to be bulk grain movements.

Please note that this is simplified worked example to illustrate the application of cost-benefit analysis in a rail freight context. Specific projects will have their own complexities and will require more sophisticated modelling and assessment.

2. Options

This example examines a single Project Case option compared to the Base Case. For simplicity, it is assumed the freight task is 300,000 tonnes of bulk grain, all of which is conveyed by road in the Base Case. The existing arrangements are for road movements from local silo/storage to a regional hub where the product is transhipped onto rail for the line haul to an export port terminal. The Project Case assumes this grain will be recaptured and travel direct from local silo to export port thus eliminating road haul and transhipping.

The logistics options are depicted in Figure 1 below.

It is assumed that minimal maintenance is carried out on the branchline which is in a semi mothballed state.

Figure 1: Alternative supply chains

Base Case

Do Minimum: Maintain the branchline to its current state without any improvement to the infrastructure and operations. Retention of the freight on trucks travelling between silos will incur significant expenditure to rehabilitate the existing road.

Project Case Option

Branchline Upgrade: The improvements will consist of partial re-rail and re-sleeper and reinforcement or replacement of multiple culverts to permit increased axle loads to mainline standards. A range of urgent road repairs is also required even in the Project Case.

3. Benefits and costs

Table 1 lists the benefits and costs that have been monetised in this worked example.

Table 1: Monetised benefits and costs

	Monetised
Benefits	
Line haul cost savings.	✓
Reduced product deterioration	✓
Transhipping cost savings	✓
Environmental externality benefit	✓
Reduced road accidents	✓
Reduced road maintenance	✓
Residual Value	✓
Costs	
Construction costs	✓
Operating and maintenance costs	✓

A more advanced assessment would consider several other items: potentially improved rail rollingstock productivity; net change in road and rail revenue. The increase in rail revenue is more than likely offset by the decrease in truck revenue. The revenue streams are considered to be based on a mark-up on operating costs. In a comprehensive assessment both revenues from both modes should be modelled.

4. Inputs and assumptions

4.1 General

Base year and price year: December 2018. This price year is used so that there is a direct link to the parameter values in ATAP M3.

Real discount rate: 7% for main central analysis, 4% and 10% for sensitivity tests

Construction period: To simplify calculations, the construction phase has been compressed into a single year, 2019. The improved rail line is fully operational by the start of 2020.

Appraisal period: 51 years, consisting of one-year construction and 50 years post construction (recommended in ATAP T2 for rail projects).

Investment cost: The capital costs are $25 million in the Project Case, and $12 million in the Base Case. The Project Case includes some priority road upgrades whereas the Base Case assumes a partial rehabilitation.

Asset (economic) life: Table 2 lists the assets involved in the Base Case and Project Case. The table also shows the estimated economic life of each asset. The economic life of various components is sourced from ATAP M3 TABLE 24**.** The economic life of the road assets is shorter than the appraisal period, requiring the road assets to be reinvested at the end of their economic life in year 25 in both the Base Case and the Project Case.

Table 2: Capital cost ($m)

Item	Cost $m	Economic life (years)	% life remaining at end of appraisal period	Residual value, $m
Base Case				
Road rehabilitation	12	25	0%	–
Total	12			–
Project Case				
Sleepers	7	50	0%	–
Rails	7	100	50%	3.5
Culverts and bridge reinforcements	10	50	0%	–
Road rehabilitation	1	25	0%	–
Total	25			3.5

Reinvestment: The economic life of some of the rail asset components exceed the appraisal period, As a result, there will be a residual value, to be included in the last year of the appraisal period.

Residual value methodology: Straight line depreciation method using the following formula:

$$\text{Residual Value (Straight Line Depreciation)} = \text{Capital cost} \times \frac{\text{Asset Life Remaining After Appraisal Period}}{\text{Asset Life}}$$

See ATAP T2, SECTION 3.3 for a general discussion on residual value methods.

Table 2 shows the calculation of residual value.

Growth rate:

For simplicity, it is assumed the annual volume of grain to be transported is static at 300,000 tonnes per year. Although, generally, advances in technology provide for increased yields over time, it is assumed the available agricultural footprint will not change. Thus, quantities will be the same in the future.

For more sophisticated examples, it may be appropriate to slowly grow the crop over time based on long-term time series data and incorporating variables such as reduced yields in times of adverse climatic conditions such as El Nino. But this will depend on individual circumstances.

4.2 Logistics simulation

Very sophisticated applications may require specific modelling software, e.g. discrete event simulation but for most cases a simple spreadsheet-based model is sufficient (as with this worked example). The purpose in modelling is to understand the resource requirements.

Agricultural products are generally seasonal in nature with relatively short logistics windows partially to protect product integrity and to reduce storage costs. It is assumed that there is a three-months per year cycle. This equates to about 150 trains each with a 2,000 tonne payload (two trains per day most days) or 10,000 semi-trailers with 30 tonnes each or about 140 trucks per day. The truck-based loads may be a little high, thus perhaps overstating the performance of the road operation.

For products with non-seasonal all-year logistics requirements such as many industrial products or groceries, an alternative approach is required, which spreads peaks better.

Table 3 summarises the key operational inputs for the current example.

Table 3: Logistics supply chain summary

Item	Base	Option 1
Transport mode	Road	Rail
Tonnes per year	300,000	300,000
Trucks trips per year	10000	
Tonnes per truck	30	
Trains per year		150
Tonnes per train		2,000
Terminal time per trip	0.5	3
Line haul time per trip	2.5	4
Operating hours per year (terminal + line haul)	30,000	1,050
Operating km per year	2,000,000	30,000
NTK per year	30,000,000	30,000,000
GTK per year	60,000,000	52,200,000

4.3 Base Case

Transhipping is required in the Base Case. It is assumed the cost of this activity is $0.60 per tonne. While the act of transhipping is generally very safe in terms of product integrity and freedom from spoilage and contaminants, there are always some risks and wastage associated. It is assumed 0.1% is lost.

Transport cost per truck trip

Freight cost per truck trip is calculated by applying the unit time and vehicle operating costs for six-axle semi-trailers from ATAP PV2 to the trip time and distance figures in Table 3. The unit costs used are: $51.70 per hour for time cost; $1.20 per truck-km vehicle operating cost. The cost is then annualised based on the number of truck-kms.

4.4 Project Case

Transport cost per train trip

Rail transport costs are calculated by combining the key statistics in Table 3 with the parameter values in **Table 4**.

Table 4: Summary of rail parameter values

Parameter	Value ($)	Unit	Source	Comment
Locomotive fuel	7.8	per km	M3 Table 26	Standard 3000hp locomotive on flat terrain
Locomotive crew	200	per working hour	M3 Table 24	
Locomotive capital cost	670,000	per year	M3 Table 22	Standard 3000hp at 7%
Locomotive Servicing	1.3	per km	M3 Table 28	For running component
Locomotive Servicing	20	per hour	M3 Table 28	For time based component
Wagon capital cost	13,000	per year	M3 Table 23	Double slot container wagon at 7%
Wagon maintenance	70	per 000km	M3 Table 29	Double slot container wagon
Overhead	15%		M3 Table 33	Adjusted for just transport costs
Variable track maintenance	2	per 000 GTK	M3 Table 31	Medium range
Routine track maintenance	15,000	per track km pa	M3 Table 30	Low use branchline

Table 5 summarises the resulting rail transport costs in the Project Case on a per train basis.

Table 5: Estimated train operations costs

Item	Forward Loaded	Return (Empty)	Round Trip
Fuel	1,560	780	2,340
Crew	1,000	800	1,800
Locomotive Servicing	420	320	740
Wagon Servicing	313	313	625
Locomotive Capital	1,276	957	2,233
Wagon Capital	310	232	542
Overhead	492	343	835
Cost per train	5,366	3,742	9,108

The variable track component has been removed from the train operating cost model and is placed within the overall operations and maintenance category. This slightly complicates the calculations going forward if a growth factor is included, but provides for greater transparency.

Environmental benefit

The switch of this traffic from road to rail results in reduction in environmental externality costs. The pending update of ATAP PV5 reports the environmental externality costs of rural freight transport as follows: truck (HCV) $20 per 1000 tonne-kms; rail $11 per 1000 tonne-kms. A switch of this freight task from road to rail will therefore result in a reduction of external environmental impacts of $9 per 1000 tonne-kms travelled.

Road safety benefit

The reduction in heavy vehicle movements will produce a reduction in road safety incidents. The safety benefits are based on a road crash cost of $87,000 per million vehicle-kms travelled (TfNSW, 2018, Table 60).

5. Benefit and cost time streams

Annual benefit and cost time streams are shown in **Figure 2** to **Figure 4** and **Table 6**.

Figure 2 Total benefits time stream

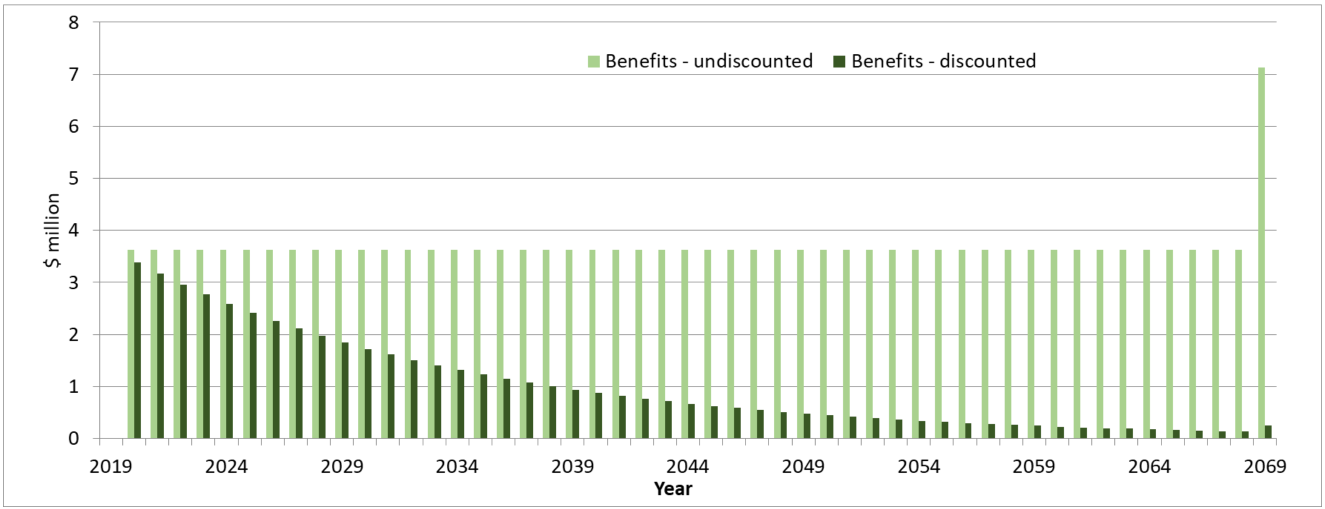

Figure 3 Total cost time streams

Figure 4 Cumulative discounted net benefit time stream

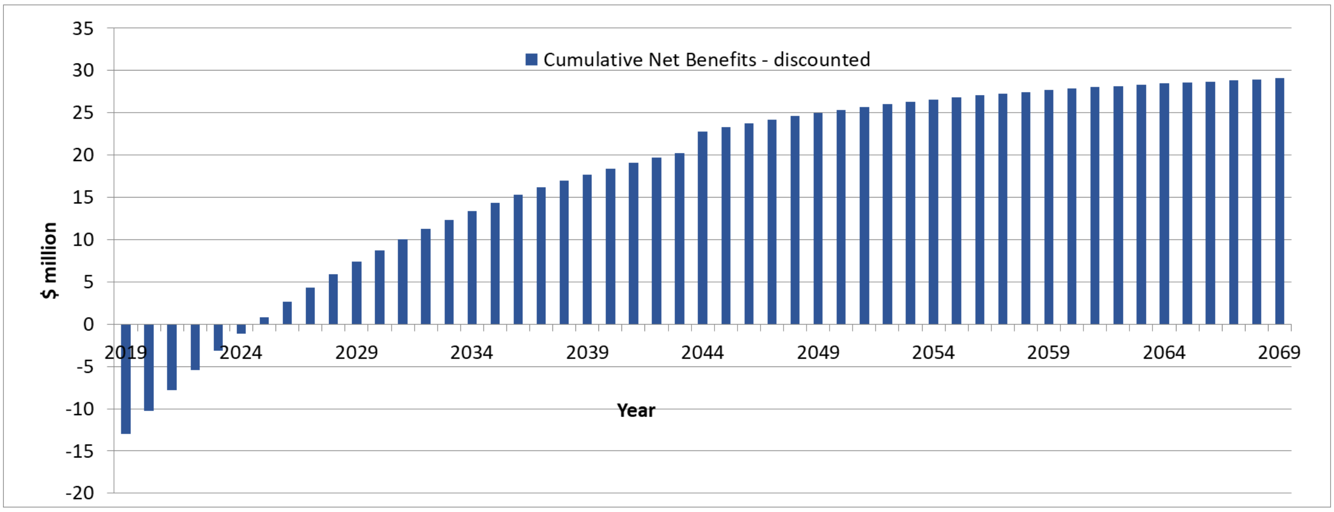

Table 6: Undiscounted benefit and cost time streams ($000)

Year		Base Case	Project Case	Change	Base Case	Project Case	Change	Total cost change	Freight Cost Savings	Reduced product spoilage	Reduced transhipping cost	Environmental externality Benefits	Safety Benefits	Residual Value	Total Benefits	Net Benefit (Benefits - Cost)
0	2019	12	25	13	0.00	0.00	0.00	13.00								-13,000
1	2020				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
2	2021				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
3	2022				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
4	2023				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
5	2024				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
6	2025				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
7	2026				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
8	2027				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
9	2028				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
10	2029				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
11	2030				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
12	2031				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
13	2032				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
14	2033				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
15	2034				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
16	2035				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
17	2036				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
18	2037				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
19	2038				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
20	2039				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
21	2040				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
22	2041				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
23	2042				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
24	2043				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
25	2044	12	1	-11	0.38	1.10	0.73	-10.27	2,585	60	180	626	174		3,625	13,898
26	2045				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
27	2046				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
28	2047				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
29	2048				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
30	2049				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
31	2050				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898

Worked Example W3 Freight Rail: An upgraded regional branchline

Year		Base Case	Project Case	Change	Base Case	Project Case	Change	Total cost change	Freight Cost Savings	Reduced product spoilage	Reduced transhipping cost	Environmental externality Benefits	Safety Benefits	Residual Value	Total Benefits	Net Benefit (Benefits - Cost)
32	2051				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
33	2052				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
34	2053				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
35	2054				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
36	2055				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
37	2056				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
38	2057				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
39	2058				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
40	2059				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
41	2060				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
42	2061				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
43	2062				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
44	2063				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
45	2064				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
46	2065				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
47	2066				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
48	2067				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
49	2068				0.38	1.10	0.73	0.73	2,585	60	180	626	174		3,625	2,898
50	2069				0.38	1.10	0.73	0.73	2,585	60	180	626	174	3,500	7,125	6,398

6. Results summary

Table 7: Benefit and cost results – Central assessment (7% discount rate, input value best estimates)

	Present Value $m
Benefits	
Transport cost savings	35.67
Reduced product deterioration costs	0.83
Transhipment cost savings	2.48
Environmental externality benefits	8.64
Safety benefits	2.4
Residual value	0.12
Costs	
Construction costs	10.97
Maintenance and operating costs	10.02
Results	
PVB	50.14
PVOC	10.02
PVIC	10.97
PVC = PVIC + PVOC	21.00
NPV = PVB – PVC	29.14
BCR1 = PVB / PVC	2.39
BCR2 = (PVB – PVOC) / PVIC	3.66
FYRR	21%
Break Even Year	6
IRR	22%

Table Notes:

1. All benefit and cost components are calculated as the incremental change between Base Case and Project (Option) Case.
2. PV stands for present value; PVB is the PV of economic, social and environmental benefits, includes residual value, and excludes operating and maintenance costs; PVOC is the PV of operating and maintenance costs; PVIC is the PV of investment (i.e. capital) costs.
3. BCR definitions: BCR1 and BCR2 are both used by Australian jurisdictions – see ATAP Part T2 section 10. BCR2 is equivalent to NPVI (the index of investment efficiency) minus 1.
4. The breakeven year is the year in which the sum of the annual discounted benefits becomes equal to the sum of the discounted costs. After that year, the former starts to exceed the latter.

Table 8: Sensitivity testing results

Sensitivity Test	PVB ($m)	PVIC ($m)	PVOC ($m)	NPV ($m)	BCR1	BCR2	FYRR
Central assessment (7% discount rate, input value best estimates)	50.1	11.0	10.0	29.1	2.39	3.66	21%
4% discount rate	78.4	8.9	15.6	53.9	3.20	7.07	21%
10% discount rate	36.0	12.0	7.2	16.8	1.87	2.40	20%
+20% capital cost	50.2	13.2	10.0	27.0	2.16	3.05	19%
- 20% capital cost	50.1	8.8	10.0	31.3	2.67	4.57	28%
+20% benefits	60.2	11.0	10.0	39.2	2.87	4.57	28%
-20% benefits	40.1	11.0	10.0	19.1	1.91	2.74	17%
+20% volume	60.1	11.0	10.0	39.1	2.86	4.57	28%
-20% volume	40.1	11.0	10.0	19.1	1.91	2.74	17%
+20% transport cost savings	57.3	11.0	10.0	36.3	2.73	4.31	26%
-20% transport cost savings	43.0	11.0	10.0	22.0	2.05	3.01	18%
+20% congestion savings	50.3	11.0	10.0	29.3	2.40	3.67	22%
-20% congestion savings	50.0	11.0	10.0	29.0	2.38	3.64	22%
+20% externality savings	51.9	11.0	10.0	30.9	2.47	3.81	23%
-20% externality savings	48.4	11.0	10.0	27.4	2.31	3.50	21%
+20% operations & maintenance	54.2	11.0	12.0	31.1	2.35	3.84	23%
-20% operations & maintenance	46.1	11.0	8.0	27.1	2.43	3.47	21%
Worst Case	35.1	14.3	13.0	7.8	1.29	1.55	9%

Note: The worst case scenario is based on costs increasing by 30% and benefits decreasing by 30%.

7. Results discussion

The results in **Table 7** and **Table 8** show the initiative:

- Is economically justified (NPV>0, BCR>1) in the central analysis (7% discount rate and best estimates for input values), with an NPV of $50 million and a BCR1 of around 2.4
- Is economically justified in all of the sensitivity cases
- The worst case has a BCR of around 1.3.

Based on the above results, the initiative in this worked example could be seen as having an economic justification.

It is important to stress again that this is a simplified worked example, so general conclusions about this type of project should not be drawn from the results here.

8. Supporting formulas and calculations

Base Case	Project Case
Truck	Rail
Payload per truck = 30 tonnes (t) Trucks per year = 10,000 Net tonnes per year = 10,000 x 30 = 300,000 t	Payload per wagon = 80 t Wagons per train = 25 Payload per train = 25 x 80 = 2,000 t Trains round trips per year = 300,000/2,000 = 150 Net tonnes per year = 2,000 x 150 = 300,000 t
Truck tare = 15 t per truck Payload = 30 t per truck Gross mass (to) =15 + 30 = 45 t per truck Gross mass (return) = 15 t per truck Gross mass (2-way) = 45 + 15 = 60 t/truck Trip length = 100 kms GTK = 60 x 10,000 x 100 = 60,000,000	Tare: 2 locos @ 120t = 240 t; 25 wagons @ 20 t = 500 t Total tare per train = 240 + 500 = 740 t Payload per train = 25 x 80 = 2,000 t Gross mass (to) = 740 + 2,000 = 2,740 t per train Gross mass (return) = 740 t per train Gross mass (2-way) = 2,740 + 740 = 3,480 t per train Trip length (one-way) = 100 kms GTK = 3,480 x 150 x 100 x= 52,200,000
Statistics per round trip: Terminal time = 0.5 hrs Line haul time = 2.5 hrs Total time = 0.5 + 2.5 = 3 hrs Unit time cost = $51.70 per truck-hr Time cost = 3 x 51.70 = $155.10 Distance travelled = 100 x 2 = 200 kms Unit vehicle operating cost = $1.20 per truck-km Vehicle operating cost = 200 x 1.20 = $240 Annual truck round trips = 10,000 Annual time cost = 155.10 x 10,000 = $1.55 m Annual vehicle operating cost = 240 x 10,000 = $2.4m Total cost = 1.55 + 2.40 = $3.95 m	Statistics per round trip: Terminal time = 3 hrs Line haul time = 4 hrs Total time = 3 + 4 = 7 hrs Cost components – see Tables 4 and 5 Total cost per train = $9,108 (Table 5) Annual train round trips = 150 Annual train costs = 9,108 x 150 = $1.37m

Detailed benefit calculations are illustrated below for year 2020 (drawing on data in the tables above):

- Transport cost saving = road transport cost – rail transport cost
  = 3.95 – 1.37 = $ 2.58 million
- Reduced product spoilage = % spoilage loss x tonnes x price per tonne ($200)
  = 0.001 x 300,000 x 200 = $0.06 m
- Reduced transhipment cost = unit handling cost per tonne x tonnes handled
  = 0.6 x 300,000 = $0.18 m
- Environmental benefit = environmental cost by road – environmental cost by rail
  where environmental cost = unit environmental cost x annual gross tonne-kms
  Road environmental cost = 20 x 60,000,000/1000 = $1.20 million
  Rail environmental cost = 11 x 52,200,000/1000 = $0.57 million.
  So, environmental benefit = 1.20 – 0.57 = $0.63 million
- Road safety benefits = unit crash cost x annual truck-kms
  = 87,000/1,000,000 x 2,000,000 = $0.17 million

References

TfNSW 2018, *Principles and guidelines for economic appraisal of transport investment and initiatives*

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