TRANSPORT AND INFRASTRUCTURE COUNCIL

Australian Transport Assessment and Planning Guidelines

Worked Example: W1 Public Transport
1.1 Simple bus route improvement

May 2018

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For enquiries or feedback about this publication please contact:

ATAP Steering Committee Secretariat
Australian Transport Assessment and Planning Guidelines
Commonwealth Department of Infrastructure, Regional Development and Cities
GPO Box 594 CANBERRA ACT 2601
Email: atap@infrastructure.gov.au

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1. Problem description

Buses on a particular route are subject to considerable delay and travel time variability due to traffic congestion. These problems are expected to worsen in future due to rising road traffic flowing from more distant locations. The objective is to insulate the bus service from the traffic congestion to reduce the duration and variability of travel time for passengers.

2. Options

Land use along the corridor is well developed and there are limited opportunities to easily provide extensive separation of buses from other traffic, such as giving buses their own right-of-way. This type of extensive separation would likely not be economically worthwhile given the high cost of land acquisition and major roadworks. Prior work identified all practical opportunities to insulate buses from general traffic congestion, and a screening method was used to identify the measures with the greatest potential merit and which provide an integrated set of improvements that do not disadvantage other road users. The single Project Case option assessed below relative to the Base Case was the preferred option from the earlier rapid appraisal of a range of options.

Base Case

Option 0: Do Nothing: A 'do-nothing' scenario is considered to be the appropriate Base Case for the current appraisal because there are no other simple improvements that could make a significant difference to bus travel conditions. All such measures have already been implemented.

Project Case Option

Option 1: Bus route improvements: Sections of bus lane and traffic signal priority.

3. Benefits and costs

Table 1 list the benefits and costs and whether they have been monetised in this worked example.

Table 1 Monetised and non-monetised benefits and costs

	Monetised	Non-monetised
Benefits		
Existing users:		
Travel time savings for bus passengers	✓	
Improved reliability of bus services	✓	
Generated travel on the bus service	✓	
Disruption during construction (disbenefit)	✓	
Decongestion benefits	✓	
Increased car travel times at traffic signal priority location		✓
Environmental benefits	✓	
Residual value	✓	
Costs		

	Monetised	Non-monetised
Fixed infrastructure costs (capital, operating, maintenance)	✓	
Bus service provision costs (capital, operating, maintenance)	✓	

These benefits and costs (all incremental from the Base Case to the Project Case) are briefly summarised as follows:

- Travel time and variability will decline upon completion of the initiative, and will then remain stable relative to a worsening situation in the Base Case
- These changes will allow bus-hours and the number of buses needed to provide services in the corridor to be reduced
- A small rise in patronage is expected to result from the improved bus service, with the rise consisting of newly generated trips, trips attracted from other bus routes, and diversion from car and other modes
- Existing users (those who use the service in the Base Case) benefit by the full reduction in travel time and improvement in service reliability
- The unit economic benefit for each generated trip is equal to half of the benefit accruing to existing users – using the rule-of-a-half
- The shift of some car trips to bus will result in some decongestion benefits of the road and has been included as a benefit. While the bus priority introduced in the Project Case could result in some increase in car travel time, the resulting disbenefit has not been modelled. It has been noted as a non-monetised disbenefit and could be monetised at a later stage
- Environmental savings should result from the shift of some trips from car to bus
- Disruption to road traffic during implementation of the initiative with be a disbenefit
- A residual value remains at the end of the appraisal period and is included in the appraisal as a benefit.

4. Inputs and assumptions

4.1 General

Base year and price year: Prices are in mid-2014 prices and are discounted to a base year of 2015.

Real discount rate: 7% for the principal appraisal, with sensitivity tests at 4% and 10%.

Construction period years: 3 months in 2016. Operations to commence in 2017.

Costs: All costs reported here are incremental to the Base Case.

Investment cost:

- Fixed infrastructure: $8 million in 2016
  - Signage and other minor works – 20% of initial cost, $1.6m
  - Infrastructure works – 80% of initial cost, $6.4m

- Buses:

  As indicated in Table 2, a saving of one bus will be possible in 2022, and a further bus in 2027. The associated cost savings in those years are reflected in the 'Bus cost – Capital' column in Table 4, and are based on the quantity of bus resources calculated in Table 2 and unit costs shown in Table 3.

Asset (economic) lives:

- Fixed infrastructure:
  - Signage and other minor works – 10-year life
  - Infrastructure works – 20-year life
- Buses: 20-year life

Appraisal period: The implementation period (1 year) plus 15 years of operation. An appraisal period of 20 years is probably a more logical alternative—a 15-year period was selected to demonstrate a residual value calculation.

Reinvestment:

- Signage and other minor works: reinvest in 2026 (end of economic life)

Residual value methodology: Straight line depreciation method, with residual value shown as a benefit in the final year of appraisal. The residual value in 2031 is based on:

- Fixed infrastructure:
  - Re-invested signage and other minor works – remaining useful life of 5 years
  - Initial infrastructure works – remaining useful life of 5 years
- Buses: Applies to the avoided buses discussed above. The residual value in 2031 is based on:
  - For bus avoided in 2022 – 11 years of remaining life
  - For bus avoided in 2027 – 16 years of remaining life.

Growth rates: Ongoing costs and benefits are estimated for 2017, 2022 and 2027. Data for intermediate years is based on a constant percentage growth, with values after 2027 based on extrapolation. Road traffic growth of 2% per annum is used.

Annual operating and maintenance costs:

- Fixed infrastructure: Assumed to equal 3% of the capital cost (see Table 3)
- Buses: Calculated in a bus operating cost model using parameters in Tables 2 and 3.

4.2 Travel demand

Forecasts have been prepared for the Base Case and Project Case for each of 3 future years (see Table 2 and Table 3). Introduction of the initiative is expected to increase average bus speeds by 1 kph (to 22 kph) in 2017 and to enable this speed to be maintained into the future. By contrast, average travel speed is forecast to deteriorate in the absence of the initiative (the Base Case). Service reliability does not change in the base case and is expected to improve in the project case, with the average minutes late declining by 0.5 minutes in 2017, rising to 1.5 minutes in 2027. These average minutes late numbers are presented here as daily averages – ideally, they should be assessed separately for peak and off-peak periods.

Estimated travel demand for the morning peak 2-hour period is shown in Table 2. The area served by the bus service is fully developed, and hence no underlying patronage growth trend is forecast to occur over time. Some generated demand is expected to result from the initiative, with the estimated quantity based on the decline in average travel time and the related elasticity of demand. The resulting rise in patronage is modest and can be accommodated using spare capacity in buses (i.e. without the need to increase the number of services).

4.3 Public transport resource needs

Bus resource needs, including the number of buses and bus-hours and bus-km of service, are reported in Table 2 and are based on other data in this table and Table 3.

Table 2 Base and project case conditions

	Base Case			Project Case		
	2017	2022	2027	2017	2022	2027
Service characteristics						
Service headway in AM peak 2 hours (mins)	10	10	10	10	10	10
Route length (km)	12	12	12	12	12	12
Average travel speed						
Average annual decline (% over previous period)		2%	2%		0%	0%
Average travel speed (kph)	21.0	19.0	17.2	22.0	22.0	22.0
Average round trip travel time (mins)	79	86	94	75	75	75
Service reliability						
Equivalent time to a minute late ratio	4.8	4.8	4.8	4.8	4.8	4.8
Reduction in average minutes late	-	-	-	0.5	1.0	1.5
Bus resources and costs						
Number of buses required	9	10	11	9	9	9
Bus-km of service in the AM peak 2 hours	288	288	288	288	288	288
Bus-hr of service in the AM peak 2 hours	13.7	15.1	16.7	13.1	13.1	13.1
Annual bus-km of service ('000)	479.9	479.9	479.9	479.9	479.9	479.9
Annual bus-hr of service ('000)	21.9	24.1	26.6	20.9	20.9	20.9
Annual bus operating costs ($m, mid-2014 prices)	1.85	1.97	2.11	1.80	1.80	1.80
Patronage						
Base (existing) patronage						
Peak 2-hour patronage	360	360	360	360	360	360
Annual patronage ('000)	458.9	458.9	458.9	458.9	458.9	458.9
Annual passenger travel time ('000, hrs)	131.1	144.8	159.8	125.2	125.2	125.2
Generated patronage						
% of base patronage	-	-	-	1.4%	4.7%	8.3%
Annual generated patronage (‘000)	-	-	-	6.6	21.6	38.1

Table 3 Other appraisal parameters

Parameter	Value[1]
Bus service features	
Layover time per round trip (mins)	10*
Maintenance & operational spare buses (% of base fleet)	10%
Share of weekday bus-km in AM peak 2 hours	17.6%
Share of weekday bus-hours in AM peak 2 hours	18.4%
Equivalent weekdays per annum	293.3
Unit bus operating costs (mid-2014 prices)	
On-vehicle crew ($/bus-hour)	42.00
Direct vehicle operating costs ($/bus-km)	1.15
Overhead costs (% on other operating costs)	20%
Profit margin (% on total operating costs)	5%
Bus capital and periodic rehabilitation costs	
Capital cost of bus ($m)	0.48
Equivalent average annual cost of rehabilitation ($'000)	4.0
Incr. O&M costs for fixed infrastructure (% of infra. cost)	3%
Patronage	
Average number of boardings/round trip	60*
Average trip length (km/passenger)	6*
Share of weekday bus-hours in peak 2 hours	22.4%
Equivalent weekdays per annum	285.6
Generated demand	
Elasticity of demand with respect to travel time	-0.3
Share of generated demand diverted from cars	20%
Road traffic	
AADT (vehicles per day)	20,000
Share of trucks in AADT	5%
Share of car travel for business	20%
Traffic growth rate (% per annum)	2%
Private car occupancy rate (persons/vehicle)	1.6.
Business car occupancy rate (persons per vehicle)	1.4
Truck occupancy rate	1.1
Value of travel time	
$s, June 2013 values	
Private cars	14.99
Business cars	48.63
Trucks	40.00
Index to mid-2014 (ABS 6302.0)	1.012*
$s, Mid-2014 prices	
Private cars	15.17
Business cars	49.21
Trucks	40.48
Decongestion	
Average length of trip diverted from car (kms)	5
Unit decongestion benefit ($/veh-km)	0.5
Disruption during construction	
Length of road over which speed reduction occurs (kms)	0.5
Average road speed in Base Case (kms/hr)	60
Average road speed in Project Case (kms/hr)	30
Equivalent weekdays per annum	270
Duration of construction period (months)	3

(1) Default values set out in the Guidelines are used. Exceptions, which are marked with an *, are based on best judgement. Monetary values are in mid-2014 prices unless otherwise indicated

(2) The share of generated demand diverted from cars is based on ATAP M1 Table 3 Melbourne SmartBus. Although the numbers quoted there are for major initiatives, they have been used here to illustrate application of the methodology

(3) Values of travel time and occupancy rate are based on ATAP PV2 Table 12. The values for truck are an approximate average across the wide range of truck types, and includes both occupant and freight time

(4) Unit decongestion benefit is based on ATAP Part M1 section 4.8.3,using an average congestion level across the day of light to medium.

4.4 Other parameter values

The estimation of decongestion benefits, the disbenefit of disruption during construction and environmental benefit require information about the road traffic stream along the route where the bus improvements will take effect. Table 3 provides relevant details of road traffic. Table 3 also provides the remaining parameter values required for the assessment.

5. Benefit and cost time streams

Annual monetised benefit and cost time streams are shown in Table 4 and Figures 1 to 3.

Table 4 Undiscounted benefit and cost time streams

Year	Costs					User benefits					Other benefits			
	Fixed infrastructure costs		Incremental bus costs		Total	Existing users		Generated public transport trips	Decongestion	Disruption	Environment	Residual Value	Total Benefits	**Net benefits**
	Capital	Ops & Maint.	Capital	Ops & Maint.		Travel time savings	Improved reliability							
2016	8.00	0.00	0.00	0.00	8.00	0.00	0.00	0.00	0.00	-0.25	0.00		-0.25	-8.25
2017	0.00	0.24	0.00	-0.05	0.19	0.09	0.28	0.00	0.002	0.00	0.000		0.37	0.19
2018	0.00	0.24	0.00	-0.07	0.17	0.11	0.32	0.00	0.003	0.00	0.001		0.44	0.27
2019	0.00	0.24	0.00	-0.08	0.16	0.15	0.37	0.01	0.003	0.00	0.001		0.52	0.37
2020	0.00	0.24	0.00	-0.11	0.13	0.18	0.42	0.01	0.004	0.00	0.001		0.62	0.49
2021	0.00	0.24	0.00	-0.14	0.10	0.23	0.48	0.01	0.005	0.00	0.001		0.74	0.64
2022	0.00	0.24	-0.48	-0.17	-0.41	0.30	0.56	0.02	0.007	0.00	0.001		0.88	1.30
2023	0.00	0.24	0.00	-0.19	0.05	0.33	0.60	0.02	0.008	0.00	0.002		0.97	0.93
2024	0.00	0.24	0.00	-0.22	0.02	0.37	0.65	0.03	0.008	0.00	0.002		1.07	1.05
2025	0.00	0.24	0.00	-0.24	0.00	0.42	0.71	0.04	0.009	0.00	0.002		1.18	1.18
2026	1.60	0.24	0.00	-0.27	1.57	0.47	0.77	0.05	0.011	0.00	0.002		1.30	-0.27
2027	0.00	0.24	-0.48	-0.31	-0.55	0.53	0.84	0.06	0.012	0.00	0.003		1.43	1.98
2028	0.00	0.24	0.00	-0.34	-0.10	0.59	0.91	0.07	0.013	0.00	0.003		1.58	1.68
2029	0.00	0.24	0.00	-0.38	-0.14	0.66	0.98	0.09	0.015	0.00	0.003		1.75	1.89
2030	0.00	0.24	0.00	-0.43	-0.19	0.74	1.07	0.11	0.017	0.00	0.004		1.93	2.12
2031	0.00	0.24	0.00	-0.48	-0.24	0.83	1.16	0.13	0.019	0.00	0.004	1.75	3.89	4.13
PV (7%)	8.24	2.04	-0.51	-1.67	8.10	2.87	5.10	0.28	0.07	-0.23	0.01	0.59	8.69	0.59
Share	102%	25%	-6%	-21%	100%	33%	59%	3%	1%	0%	-3%	7%	100%	

(1) All figures (except share) are in undiscounted $ million units.

Figure 1 Total benefits, total cost and net benefits time streams

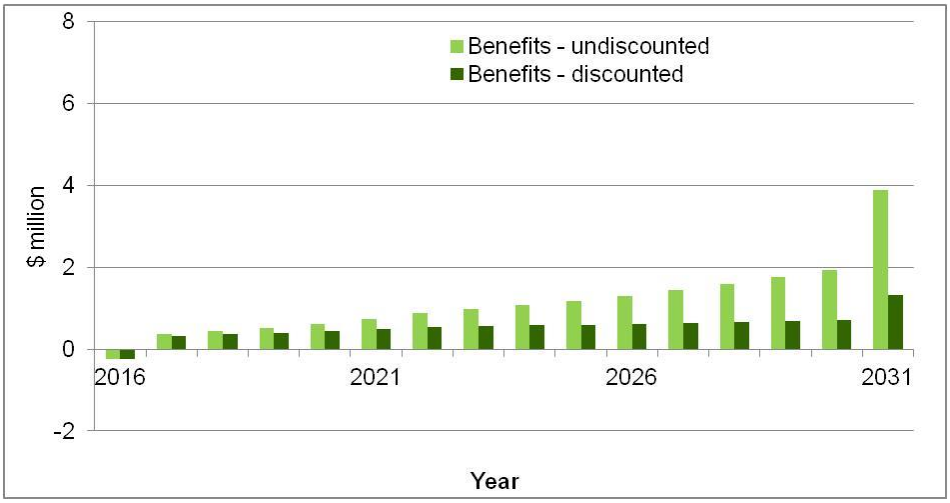


Figure 2 Total costs time stream

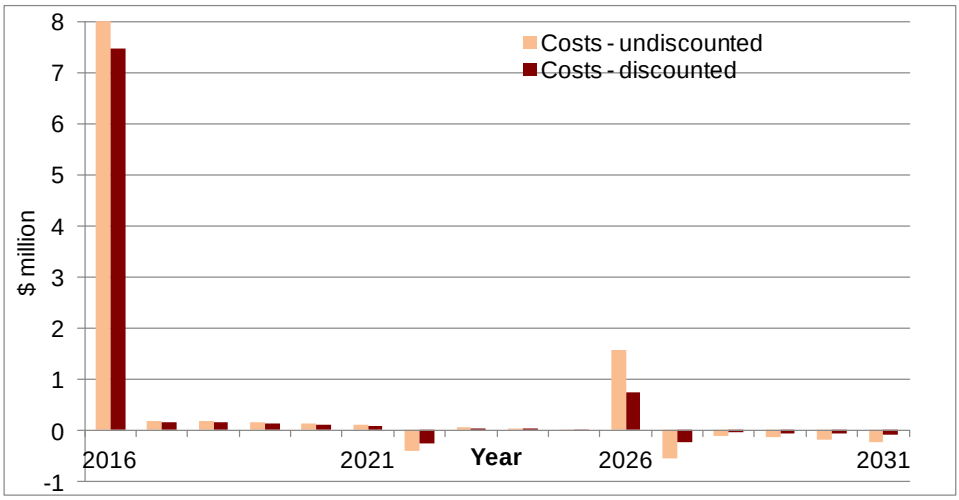
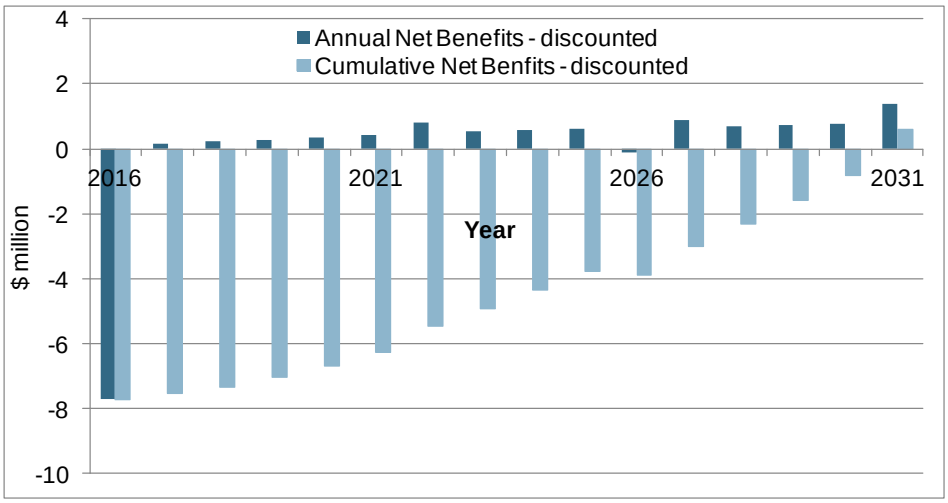


Figure 3 Net benefits time streams



6. Results summary

Table 5 Discounted benefit and cost results – Central assessment (7% discount rate, input value best estimates)

Benefits, $m	
Existing users:	
Travel time savings	2.87
Improved reliability	5.10
Generated travel	0.28
Disruption during construction	-0.23
Decongestion	0.07
Environment	0.01
Residual value	0.59
Costs, $m	
Fixed infrastructure capital costs	8.24
Fixed infrastructure operating and maintenance costs	2.04
Incremental bus capital costs	-0.51
Incremental bus operating and maintenance costs	-1.67
Results	
PVB, $m	8.69
PVIC, $m	7.72
PVOC, $m	0.37
PVC = PVIC + PVOC	8.10
NPV = PVB – PVC	0.59
BCR1 = PVB / PVC	1.07
BCR2 = (PVB – PVOC) / PVIC	1.08
FYRR	2.1%

Table Notes:

1. All figures are $ million present value except for BCR and FYRR. 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.

Table 6 Sensitivity testing results

	PVB	PVIC	PVOC	NPV	BCR1	BCR2	IRR	FYRR
Central assessment (7% discount rate, input value best estimates)	8.69	7.72	0.37	0.59	1.07	1.08	8%	2.1%
Sensitivity Tests[(4)]								
1. Low discount rate (4%)	11.82	8.07	0.31	3.44	1.41	1.43	7.8%	2.1%
2. High discount rate (10%)	6.53	7.43	0.40	-1.30	0.83	0.82	7.8%	2.1%
3. Increase capital costs by (25%)	8.69	9.66	0.37	-1.34	0.87	0.86	5.4%	1.7%
4. Decrease capital costs by (5%)	8.69	7.34	0.37	0.98	1.13	1.13	8.4%	2.2%
5. Increase maintenance costs by (10%)	8.69	7.72	0.41	0.56	1.07	1.07	7.8%	1.9%
6. Decrease maintenance costs by (10%	8.69	7.72	0.33	0.63	1.08	1.08	7.9%	2.3%
7. Increase benefits by (10%)	9.50	7.72	0.37	1.40	1.17	1.18	6.5%	2.5%
8. Reduce benefits by (25%)	6.67	7.72	0.37	-1.43	0.82	0.81	4.6%	1.1%

Table notes:

1. The asymmetric changes reflect a common tendency for the cost of initiatives to be higher than expected and the benefits to be less than expected

7. Results discussion

The results in Tables 5 and 6 show the initiative:

- Is economically justified in the central analysis (7% discount rate and best estimates for input values) with an NPV of $0.59 million and a BCR of around 1.1
- Is not justified for the following cases: a discount rate of 10%; capital costs 25% higher; benefits reduced by 25%
- It is economically justified in other sensitivity tests.

The appraisal shows that the economic justification of the initiative is sensitive to any underestimation of capital costs and overestimation of benefits. This means that estimates of benefits and capital costs need to be carefully scrutinised before a final decision to proceed with the initiative is taken.

8. Supporting calculations and formulas

Detailed benefit calculations are illustrated below for year 2022 (drawing on data in Table 2 and Table 3):

- Travel time savings = change in annual passenger travel time * value of travel time
  = ((144,800 – 125,200) * 14.99) / 10^6 = $ 0.30 million
- Improved reliability = equivalent time to a minute late ratio * reduction in average minutes late * value of travel time * number of passengers affected
  = (4.8 * 1 / 60 * 14.99 * 458,900) / 10^6 = $ 0.56 million
- Generated travel = half of the total benefit to existing users per user * number of generated trips
  = ((0.30 + 0.56) * 10^6 / (458,900)) *0.5 * 21,600 / 10^6 = $ 0.02 million
- Decongestion = annual car veh-km reduction (i.e. generated annual patronage * proportion of trips diverted from cars / average occupancy rate * average trip length of diverted trip) * unit decongestion cost
  = (21,600 * 0.2 / 1.6 * 5) * 0.5 / 10^6 = $ 0.0067 million
- Environment = annual car veh-km reduction * unit environmental cost
  = (21,600 * 0.2 / 1.6 * 5) * 0.11 / 10^6 = $ 0.0015 million

In addition, disruption during construction is a one-off disbenefit that occurs during the construction period and is calculated as follows:

- Disruption during construction disbenefit = delay per km per vehicle * number of affected kms * number of affected vehicles * equivalent weekdays per annum * duration of construction period * value of time travel time
  - when estimated for private cars = (1/30 – 1/60)* 0.5 * (20,000 * [1 – 0.05] * [1 – 0.2]) * 270 * 3/12 * 14.99 * 1.012 / 10^6 = $ 0.13 million

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