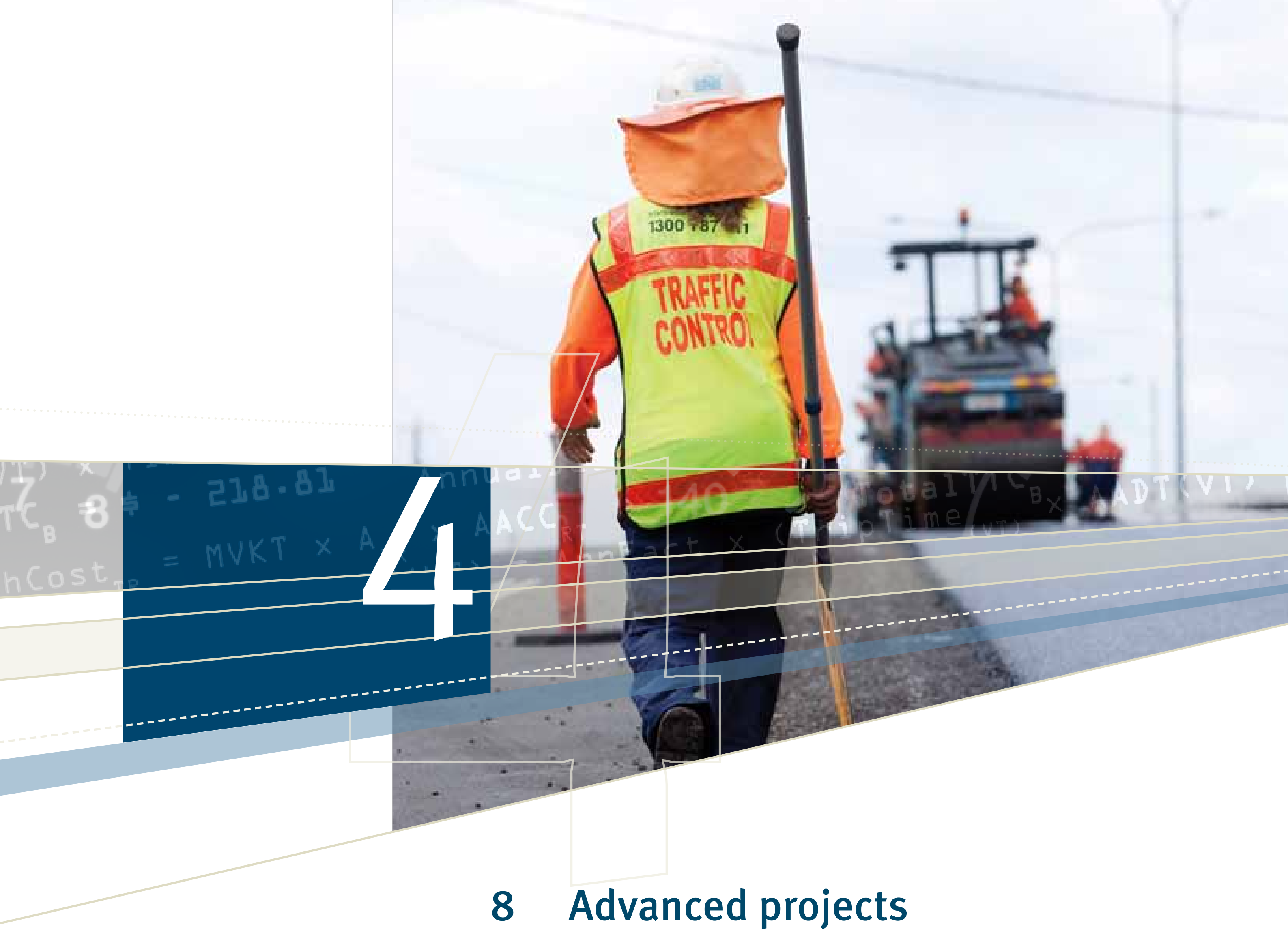


8 Advanced projects

This section provides the methodologies and algorithms contained in CBA6 for the advanced modules. This section builds on the previous explanations of road user costs such as VOC, TTC and accident costs and applies those calculations to advanced projects. It outlines the methodologies applied to derive the following benefits/costs:

- flooding/diversions (diversions with a road closure)
- road closures (road closure with no diversion)
- generated traffic
- livestock damage
- intersections
- overtaking lanes.

All examples in this chapter are consecutive quantifications of a single year's user cost for the B-double vehicle type.

8.1 Road closure with diverting route

Flood immunity projects require a detailed understanding of both the road network and road user behaviour. As in Section 5.4.5 of the *User Guide*, road user responses to flooding can vary depending on the frequency, severity and extent of flooding. Flood warning times and the availability of alternative routes will also affect the decisions made by motorists. The following three options exist for motorists affected by flooded roads:

- Wait – remain at the flood site for waters to subside.
- Divert – use an alternative route around the flood affected area.
- Do not travel – choose not to travel at all.

Example: Flooded road

In this example for a flooded road, the following assumptions apply:

- 10% – wait at the flooding site (wait for the flood to subside).
- 20% – divert to another route.
- 70% – choose not to travel during the flooding event at all.

Note: Proportions of road user behaviour must equal 100%.

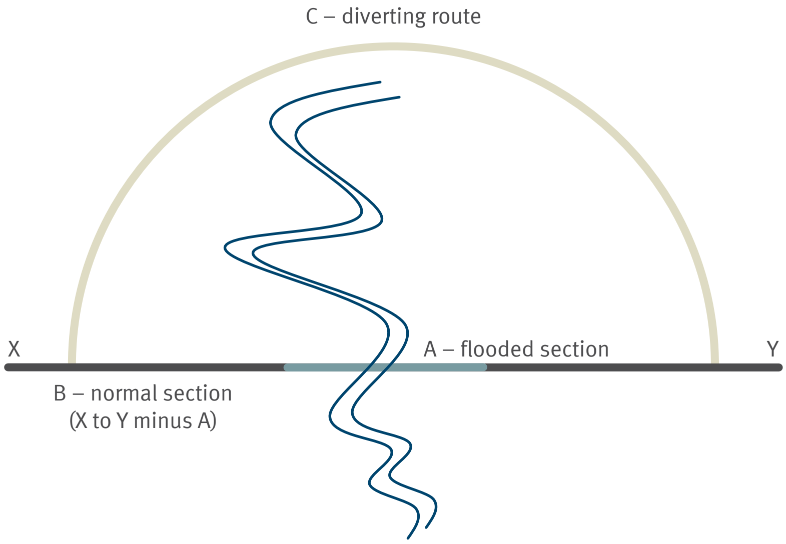
For all road closure projects CBA6 requires road closure information associated with local flooding and data on the AATOC and the ADC for the base and project cases.

Note: For further details on the costs of not travelling see Section 2.4.1.3 of the *Theoretical Guide*. CBA6 does not calculate road user costs for existing traffic.

Figure 3 illustrates the relevant sections of a flooding diversion which are identified as:

- Section A is the flood affected section, which is to be upgraded.
- Section B is the normal full length of the road, and is assumed to have the same road configuration as section A in the base case (prior to the upgrade). The length of B is the distance between X and Y minus the length of A.
- Section C is the diverting route, which can be substantially longer than section B and should be measured as the length along the diversion route between X and Y.

Figure 3: Flooding closure



8.1.1 Flooding data

The AATOC and ADC values are used in CBA6 to determine the waiting time during a flood event. These calculations are then used to estimate road user costs associated with the flood event. An example of flood data is shown by Table 32, and formulae for AATOC are given by Equation 48.

Table 32: Example base case flood data

Base case flood data																				
Years	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Number of floods	1	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0
Total time closed (hours)	60	0	0	0	0	0	0	68	0	0	48	0	0	24	0	0	0	0	80	0

8.1.1.1 Average annual time of closure

Equation 48: Average annual time of closure

$$AATOC = \frac{(\sum HoursClosed_i)}{Years_i}$$

Where:

- AATOC = average annual time of closure
- $HoursClosed_i$ = total hours closed per flooding event
- $Years_i$ = number of years of flood data evaluated

The AATOC is the average number of hours a road is closed per year. The AATOC calculation is used throughout CBA6's flooding diversion module to estimate the proportion of the year that the given road is closed to traffic. It is important to note that averages are based on the range of time series flood data used. An appropriate number of observations should be obtained in the sample to represent accurate closure averages.

Example: Average annual time of closure

The average annual time of closure is calculated as follows:

$$AATOC = \frac{280}{20}$$

$$AATOC = 14$$

Using the data in Table 32, the road has been closed due to flooding for 280 hours over the last 20 years, which equates to an annual average closure time of 14 hours per year.

8.1.1.2 Average duration of closure

The ADC represents the average duration of each road closure per flood and is used in CBA6 to calculate costs incurred by the road users who opted to wait. The ADC calculation is given by Equation 49.

Equation 49: Average duration of closure

The average annual time of closure is calculated as follows:

$$ADC = \frac{\left(\sum Hours\ Closed_i\right)}{\left(\sum NoFloods_i\right)}$$

Where:

- ADC = average duration of closure
- $NoFloods_i$ = total number of floods over evaluation period

Example: Average duration of closure

The ADC is calculated as:

$$ADC = \frac{280}{5}$$

$$ADC = 56$$

Based on the data in Table 32, the road is closed for an average of 56 hours per flooding event. This derivation of AATOC and ADC is used by CBA6 to calculate road user costs based on the average number of days of the year that road users are affected by a flooding event.

8.1.2 CBA6 road user cost methodology

The CBA6 road user cost methodology is founded on the average period of closure during a flooding event and the traffic behaviour during this period. Road users have three choices when confronted with a flood event. The consequence and calculated costs of these choices are described by Table 33.

Table 33: Flood/diversion road user costs calculation

Section	During flood	No flood
A	Waiting costs calculated for % waiting	Road user costs calculated as normal
B	Road user costs forgone for % diverting and % no travel	No road user costs calculated (net zero)
C	Road user costs for % diverting only	No road user costs calculated

For the flood affected section (A), road user costs are calculated during the periods where there is no flood event (% of year). During a flood event, some road users will divert and some will choose not to travel. Waiting costs are calculated for those vehicles that choose to wait at the flood affected site.

For the improved route (B) and diversion route (C), road user costs are only calculated during periods of a flood event as the road user costs are assumed not to change from the base case to the project case when there is no flood event.

During a flood event, user costs are calculated for the improved route, as it is assumed to represent user costs forgone as road users divert. For the diversion route during a flood event, road user costs are calculated based on the percentage of vehicles which choose to divert (% AADT).[1]

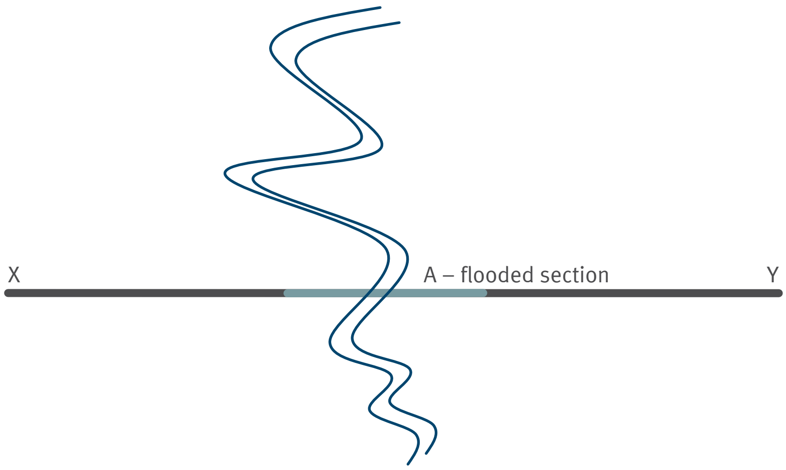
This methodology is highlighted in detailed road user cost algorithms.

- 8.1.3 Section A - project area
- 8.1.4 Section B - improved route
- 8.1.5 Section C - diversion route

8.1.3 Section A – project area

Section A refers to the flood prone section requiring the upgrade, see Figure 4. During periods when there are no flooding events, road users will not incur any additional road user costs by travelling through the section. During a flood event, the waiting costs associated with those vehicles that choose to wait at the flood site are calculated in CBA6.

Figure 4: Project area



[1] For mathematical proof of improved route methodology, see Appendix C.

8.1.3.1 Vehicle operating costs – Section A

VOC for Section A are shown by Equation 50. This equation shows that for the base and project cases VOCs are calculated for vehicles that travel on Section A for the proportion of the year that the road is open.

Equation 50: Vehicle operating costs – Section A

$$TOTVOC_A = SecLength_{BC/PC} \times \left(365.25 - \left(\frac{AATOC}{24} \times \%D\right)\right) \times \sum_i \left(AADT_i \times \frac{VOC_i}{100}\right)$$

Where:

- $SecLength_{BC/PV}$ = section length as given in the base and project case
- %D = percentage of vehicles diverting during closure (%)
- VOC_i = vehicle operating unit cost

Note: When %D is equal to 0, no vehicles divert and VOC is calculated as per equations outlined in Section 4.

Example: Vehicle operating costs – Section A

Assume that there are 100 B-doubles travelling along a 5 km stretch of highway. The traffic behaviour during a flood event is anticipated to be 50% diverting, 30% waiting and 20% choosing not to travel at all. VOCs are assumed to be 255.42 c/km. It is also assumed that the length for the upgraded Section A is 5 km, the improved route is 10 km and the diverting route is 50 km. Other road characteristics are representative of examples illustrated in Sections 2 to 4. VOC are given below:

$$TOTVOC = 5 \times \left(365.25 - \left(\frac{14}{24} \times 0.50\right)\right) \times \sum_i \left(100 \times \frac{255.42}{100}\right)$$

$$TOTVOC = \$\ 466{,}088.29$$

The total VOC incurred over the year when flooding occurs is $466 088.29.

8.1.3.2 Travel time cost – Section A

The TTC for Section A is given by Equation 51. This equation shows the base case and project case TTC.

Equation 51: Travel time cost – Section A

$$Total\ TTC_A = TripTime_{BC/PC} \times \left(365.25 - \left(\frac{AATOC}{24} \times \%D\right)\right) \times \sum_i \left(AADT_i \times VTVEHR(VT)\right)$$

Example: Travel time cost – Section A

Using the data from the previous example, trip time and VTVEHR from Table 23, the total TTC for Section A is equal to:

$$Total\ TTC = 0.07753 \times \left(365.25 - \left(\frac{14}{24} \times 0.5\right)\right) \times \sum_i (100 \times 48.40)$$

$$Total\ TTC = 0.07753 \times 364.96 \times 484.0$$

$$Total\ TTC = \$13{,}694.95$$

The total TTC incurred over the year as a result of the flood is $13 694.95.

8.1.3.3 Waiting costs – Section A

Road users who choose to wait at the flood affected site and continue their journey once the flood subsides, incur a waiting cost representative of the value of their personal and business time. The time spent waiting for the road to reopen is valued based on the number of vehicles which choose to wait at the flood affected site and the duration of the flooding event per year. The waiting time calculation is shown by Equation 52.

Equation 52: Waiting time – Section A

$$Waiting\ Time = \frac{1}{2}\left(AATOC - \frac{AATOC}{ADC} \times \left(Trunc\left(\frac{ADC}{24}\right) \times 12\right)\right)$$

Where:

- Trunc = truncates a number to an integer by removing the fractional part of the number

The ½ shown by the waiting time equation represents an even distribution of vehicles while the truncation assumes a smaller proportion of vehicles will wait the entire length of the closure once the road has been closed for more than 24 hours. The waiting time is given in hours per year which is then used to calculate the costs associated with those vehicles which choose to wait.

Example: Waiting time – Section A

Waiting cost is based on the total waiting time of the closure. The waiting time is calculated as follows:

$$Waiting\ Time = \frac{1}{2} \times \left(14 - \frac{14}{56} \times \left(Trunc\left(\frac{14}{24}\right) \times 12\right)\right)$$

$$Waiting\ Time = 7\ hrs$$

Equation 53: Waiting costs – Section A

$$CW = WaitingTime \times \frac{ADC}{24} \times AADT(VT) \times \%VehWaiting \times VTVEHR(VT)$$

Where:

- CW = costs of waiting ($)
- %VehWaiting = the proportion of vehicles waiting per vehicle type (%)

Example: Waiting costs – Section A

Waiting costs are then calculated as follows:

$$CW = 7 \text{ x } \frac{58}{24} \text{ x } 100 \text{ x } 30\% \text{ x } 48.40$$

$$CW = \$23{,}716$$

8.1.3.4 Crash costs

The crash costs for Section A are shown by Equation 54.

Equation 54: Crash costs – Section A

$$TOTACC_A = SecLength \times \left(365.25 - \left(\frac{AATOC}{24} \times \%D\right)\right) \times \sum_i \left(\frac{AADT_i}{1{,}000{,}000}\right) \times A_{TR} \times AACC_{RT}$$

Where:

- A_{TR} = total crash rate (Accidents/MVKT)
- $AACC_{RT}$ = average crash cost for road type ($)

Example: Crash costs – Section A

Total crash costs for Section A are calculated as follows:

$$TOTACC_A = 5 \times \left(365.25 - \left(\frac{14}{24} \times 0.5\right)\right) \times \sum_i \left(\frac{100}{1{,}000{,}000}\right) \times 0.325704225 \times 229{,}145$$

$$TOTACC_A = \$\ 13{,}619.06$$

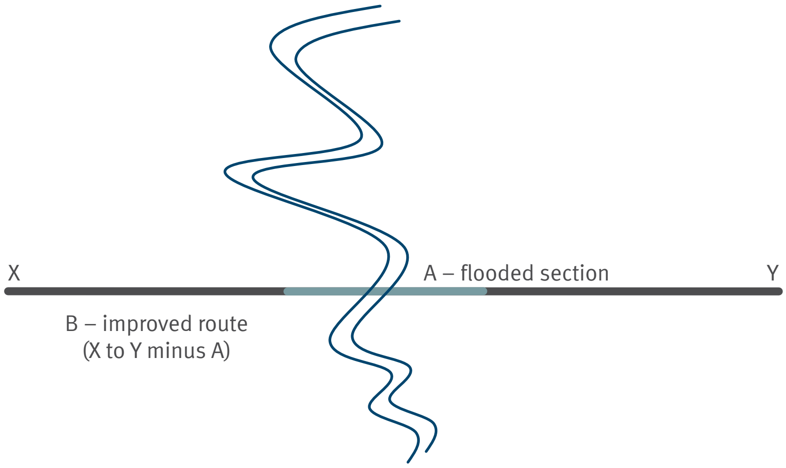
8.1.4 Section B – improved route

The improved route is assumed to be the section of road which vehicles are able to traverse during periods when the road is not closed. This route spans from the origin of the diversion route to the end of the diversion route (where the diverting traffic rejoins) minus the flooded section, see Figure 5. The assumption is made that under normal circumstances, road user costs for Section B are the same in the base and project cases and thus, the net difference would be 0.

The difference in costs that occur on the improved route when there is a flood due to road users not travelling or diverting is calculated. Based on this assumption the road user costs calculated are negative, i.e. road user costs not incurred.

For the mathematical proof of improved route methodology, see Appendix C – Mathematical proof of improved route calculation.

Figure 5: Improved route



8.1.4.1 Vehicle operating costs – Section B

VOC for Section B are shown by Equation 55.

Equation 55: Vehicle operating costs – Section B

$$TOTVOC_B = SecLength_{IR} \times \left(-\left(\frac{AATOC}{24} \times \%D\right)\right) \times \sum_i \left(AADT_i \times \frac{VOC_i}{100}\right)$$

Example: Vehicle operating costs – Section B

Calculation of VOC for the improved route is:

$$TOTVOC_B = 10 \times \left(-\left(\frac{14}{24} \times 0.5\right)\right) \times \sum_i \left(100 \times \frac{255.42}{100}\right)$$

$$TOTVOC_B = -\$744.98$$

8.1.4.2 Travel time costs – Section B

TTC for Section B are shown by Equation 56.

Equation 56: Travel time costs – Section B

$$Total\ TTC_B = TripTime_{IR} \times \left(-\left(\frac{AATOC}{24} \times \%D\right)\right) \times \sum_i \left(AADT_i \times VTVEHR(VT)\right)$$

Example: Travel time costs – Section B

Calculation of TTC for the improved route is:

$$Total\ TTC_B = 0.155 \times \left(-\left(\frac{14}{24} \times 0.5\right)\right) \times \sum_i (100 \times 48.40)$$

$$Total\ TTC_B = -\$218.81$$

8.1.4.3 Crash costs – Section B

Crash costs for section B are shown by Equation 57.

Equation 57: Section B crash costs

$$TOTACC_B = SecLength \times \left(-\left(\frac{AATOC}{24} \times \%D\right)\right) \times \sum_i \left(\frac{AADT_i}{1{,}000{,}000}\right) \times A_{TR} \times AACC_{RT}$$

Example: Crash costs – Section B

Total crash costs for Section B are:

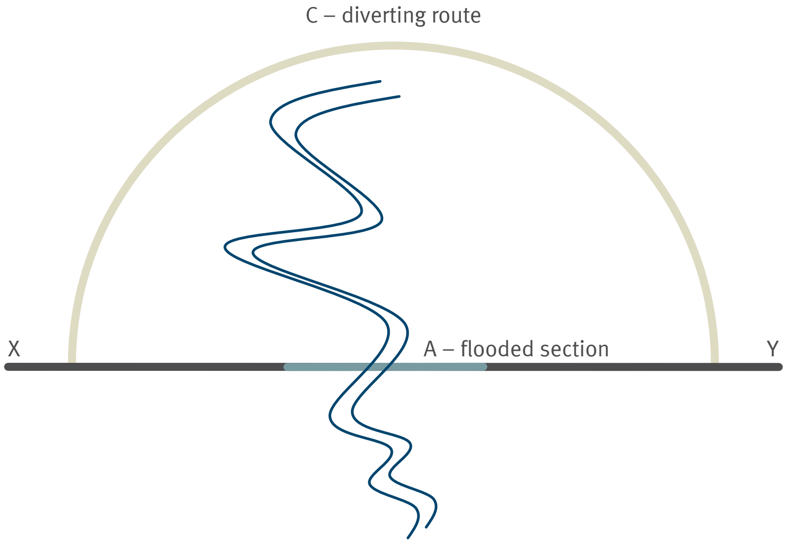
$$TOTACC_B = 10 \times \left(-\left(\frac{14}{24} \times 0.5\right)\right) \times \sum_i \left(\frac{100}{1{,}000{,}000}\right) \times 0.325704225 \times 229{,}145$$

$$TOTACC_B = -\ \$21.77$$

8.1.5 Section C – diversion route

The diverting route road user costs are only calculated during a flooding event. When a road closure occurs at Section A, some vehicles that would normally traverse the flood affected site, will now divert to an alternative route to complete their journey. The traffic diverting from Section A will join the existing traffic travelling along the diverting route.[2]

Figure 6: Diversion route



8.1.5.1 AADT – Section C

AADT on the diverting route during closure periods is determined by Equation 58. This equation incorporates the proportion of vehicles that choose to divert and the number of existing road users on the diversion route.

[2] Previous versions of the tool assumed that the road user costs of existing road users would be included in the diversion calculation during a flooding event. Old versions however, did not fully capture the road user costs incurred by existing traffic in the project case. CBA6 now omits existing traffic on the diverting route.

Equation 58: AADT – Section C

$$\%BD_{DR} = \frac{\%BD_D \times AADT_D + \%BD_E \times AADT_E}{AADT_D + AADT_E}$$

Where:

- $\%BD_{DR}$ = percentage breakdown of traffic on the diverting route
- $\%BD_D$ = percentage breakdown of diverting traffic
- $\%BD_E$ = percentage breakdown of existing traffic on the diversion route
- $AADT_D$ = traffic volume of diverting traffic
- $AADT_E$ = traffic volume of existing traffic

Example: AADT – Section C

If the diverting route consists of 5000 diverting vehicles and 2000 existing vehicles, and if 10% of diverting vehicles are B-doubles while 17% of existing vehicles are B-doubles, the percentage breakdown of B-doubles along the diverting route during a closure is:

$$\%BD_{DR} = \frac{17\% \text{ x } 2000 + 10\% \text{ x } 5000}{2000 + 5000} = 12\%$$

8.1.5.2 Traffic growth rate

Growth rate of AADT on the diversion route is made up of the increase in traffic on the normal route and the diversion route. The growth rate formula is shown by Equation 59.

Equation 59: AADT growth – Section C

$$G_{DR} = \frac{G_D \times AADT_D + G_E \times AADT_E}{AADT_D + AADT_E}$$

Where:

- G_{DR} = growth rate on diverting route (%)
- G_D = growth rate of diverting traffic (%)
- G_E = growth rate of existing traffic (%)

Example: AADT growth – Section C

If the growth rate of the diverting traffic is 5.1%, while the growth rate of the existing traffic is 3%, the growth rate of the traffic along the diverting route is:

$$G_{DR} = \frac{5.1\% \text{ x } 2000 + 3\% \text{ x } 5000}{2000 + 5000} = 3.6\%$$

8.1.5.3 Vehicle operating costs – Section C

VOC for Section C are shown by Equation 60.

Note: The traffic component is incorporated in the diversion route.

Equation 60: Vehicle operating costs – Section C

$$TOTVOC_C = SecLength_{DR} \times \frac{AATOC}{24} \times \sum_i \left((AADT_{di}) \times \frac{VOC_i}{100} \right)$$

Where:

- $AADT_{di}$ = average annual daily traffic of diverting traffic

Example: Vehicle operating costs – Section C

For the B-double example on a 50 km diverting route with similar characteristics of the upgraded section where there is no existing traffic.

$$TOTVOC_C = 50 \times \frac{14}{24} \times \sum_i \left(50 \times \frac{255.42}{100} \right)$$

$$TOTVOC_C = \$3,724.875$$

8.1.5.4 Travel time cost – Section C

TTC for Section C are shown by Equation 61.

Note: The traffic component is incorporated in the diversion route TTC.

Equation 61: Travel time costs – Section C

$$Total\ TTC_C = TripTime_{DR} \times \frac{AATOC}{24} \times \sum_i (AADT_{di} \times VTVEHR\,(VT))$$

Example: Travel time costs – Section C

TTC for the B-double example is calculated as follows:

$$Total\ TTC_C = 0.77531 \times \frac{14}{24} \times \sum_i 50 \times 48.40$$

$$Total\ TTC_C = \$1,094.48$$

Note: Trip time in this example is based on the B-double travelling at 80 km/h for the 50 km diversion route.

8.1.5.5 Crash costs – Section C

Crash costs for Section C are shown by Equation 62.

Note: The traffic component is incorporated in the diversion route.

Equation 62: Crash costs – Section C

$$TOTACC_C = SecLength \times \frac{AATOC}{24} \times \sum_i \frac{AADT_{di}}{1{,}000{,}000} \times A_{TR} \times AACC_{RT}$$

Example: Crash costs – Section C

Crash costs for the diverting route are:

$$TOTACC_C = 50 \times \frac{14}{24} \times \sum_i \left(\frac{50}{1{,}000{,}000}\right) \times 0.325704225 \times 229{,}145$$

$$TOTACC_C = \$108.84$$

8.1.6 Total road user cost – flooding diversion

Total road user costs and benefits in a flooding diversion are calculated by Equation 63.

Equation 63: Total road user costs

$$TotalRUC_{BC/PC} = RUC_A + Wait_A + RUC_B + RUC_C$$

Where:

- Road user costs = total road user costs for the relevant section (VOC + TTC + ACC)
- $Wait_A$ = waiting costs (Section A)

Example: Total road user costs

The annual net cost from the examples above is as follows:

$$Total\ Cost_{BC} = (466{,}088.29 + 13{,}694.95 + 13{,}619.06) + 23{,}716 + (-744.98 - 218.81 - 21.77) + (3724.88 + 1094.48 + 108.84)$$

$$Total\ Cost_{BC} = 493{,}402.30 + 23{,}716 - 985.56 + 4928.20$$

$$Total\ Cost_{BC} = \$521{,}060.94$$

The net benefits of a flooding/diversion are derived from road user costs calculated for all years in the evaluation for both base and project cases. The total road user costs are also discounted, see Section 9.1. Benefits are the total discounted base case costs minus the project case equivalents.

8.2 Road closures

With the exception of the diversion and improved route calculations, the road closure module in CBA6 follows the same methodology as the flooding diversion module. In road closure scenarios, such as rock falls and flooding, road users are not provided with a viable alternate route and have only two options:

- Wait at the closure site.
- Choose not to travel at all.

Based on the percentage of road users who choose to wait at the project site, CBA6 calculates the average duration of the road closure per year and waiting costs associated with the closure. Road user costs defined in Section 4 are calculated during periods where the road is not closed. Similar to the flooding diversion, those road users who choose not to travel at all during the road closure do not incur any additional road user costs for the duration of the closure.

Note: For further details on the costs of not travelling see Section 2.4.1.3 of the *Theoretical Guide*.

8.3 Intersections

The intersection module is dependent on SIDRA outputs, see Table 34. Consequently, the accuracy of the CBA6 results is dependent on the accuracy of the SIDRA modelling. Information is required for two or more years of the evaluation period, for both base and project cases. This requires at least four runs of the SIDRA intersection analysis tool depending on the number of time periods to be modelled. For this reason, generally only the peak periods are evaluated. For a more detailed discussion on the intersection module, see Section 5.5 of the *User Guide*. Data from alternative modelling tools could be used if converted to SIDRA output format.

Table 34: CBA6 intersection inputs

Period description	Period duration (hours)	Flow (veh/hour)	Average delay (seconds)	Fuel consumption (l/hour)
Morning peak	1	1000	20	100
Afternoon peak	1	2000	30	75
Non-peak	10	0	0	0
Night	12	0	0	0
Weekend day	12	0	0	0
Weekend night	12	0	0	0

One year is assumed to consist of 260.9 weekdays and 104.4 weekend days (i.e. 365.25 x 5/7 and 365.25 x 2/7). Hence, there are 260.9 morning peak periods and 104.4 weekend periods in a year.

Note: The flow rate (veh/hour) is representative of all vehicles in the fleet.

8.3.1 Delay cost calculation

The average delay in seconds is converted into hours per year per vehicle type. This calculation is shown by Equation 64.

Equation 64: Annual delay (hours)

$$Delay(VT) = \frac{averagedelay}{3600} \times flow(VT) \times duration(period) \times periods\ per\ year$$

Example: Annual delay (hours)

Using inputs from Table 34, the average delay in hours in the morning peak for a B-double at a rural intersection is calculated by the following:

$$Delay(B - Double) = \frac{20}{3600} \times 35 \times 1 \times 260.9 = 50.73\ hrs$$

The average delay of 20 seconds in the morning peak impedes the B-double fleet by 50.73 hours each year.

Note: It is assumed that there are 3.5% B-doubles out of the total vehicle flow deriving an am peak flow of 35 B-doubles.

Vehicle delay time is multiplied by the unit cost of time. The annual delay cost per vehicle type is shown by Equation 65.

Equation 65: Annual delay cost

$$Annual\ Delay\ Cost(VT) = Delay(VT) \times VTVEHR(VT)$$

Where:

- Time cost VTVEHR(VT) = TTC per vehicle ($)

Example: Annual delay cost

Following the previous example, the annual delay cost is calculated as follows:

$$Annual\ Delay\ Cost(B - Double) = 50.73 hrs \times 48.40/h$$

$$Annual\ Delay\ Cost(B - Double) = \$2455.38\ p.a$$

Delays in the morning peak cost the B-double fleet $2455 each year.

8.3.2 Fuel cost calculation

In the intersection module, only VOC incurred by road users are fuel consumption costs. The basic fuel consumption is calculated by Equation 66.

Equation 66: Basic fuel consumption

$$BFC(VT) = \left(Square(VT) \times OS^2 + \frac{Reciprocal(VT)}{OS} + Constant(VT)\right) \times FCAVF$$

Where:

- BFC(VT) = basic fuel consumption per vehicle type (L/1000 km)
- Square(VT) = model parameter
- OS(VT) = operating speed calculation for each vehicle type (30 km/h)
- Reciprocal(VT) = model parameter
- Constant(VT) = model parameter

Note: The intersection module operating speed is assumed to equal 30 km/h.

The variables in the formula are sourced from Table 10, Section 4 and are reproduced in Table 35.

Table 35: Intersection BFC variables

Vehicle type	FCAVF	Constant	Reciprocal	Square	BFC
Cars – private	1.07	37.30	1 526.20	0.01	96.40
Cars – commercial	1.07	38.90	1 883.00	0.01	140.92
Non-Articulated	1.10	49.00	3 485.10	0.02	239.97
Buses	1.10	69.40	5 451.10	0.01	239.97
Articulated	1.10	118.60	9 621.10	0.02	445.52
B-double	1.10	172.70	14 720.40	0.02	745.56
Road train 1	1.10	223.60	17 201.80	0.01	891.34
Road train 2	1.10	312.10	26 646.90	0.02	1 335.21

Source: Austroads (2005) and TMR calculations.

Example: Basic fuel consumption

Using the same B-double example at an operating speed of 30 km/h, the basic fuel consumption is calculated as follows:

$$BFC(B - Double) = 745.56\ L/1000km$$

The fuel proportion weighting for each vehicle type, based on the volume and BFC of each vehicle type, relative to the BFC of a private car is shown by Equation 67.

Equation 67: Fuel proportion

$$Fuel\ Proportion(VT) = \frac{Veh/hr(VT) \times BFC(VT)}{\sum(Veh/hr \times BCF(VT)}$$

Where:

- Veh/hr(VT) = vehicles per hour for a specific vehicle type (Flow)
- BFC(VT) = basic fuel consumption for the target vehicle, see Table 35

Example: Fuel proportion example

In the B-double example, the total fuel consumption for all vehicles is 164 052.6; this figure can be verified in Table 36. The fuel proportion is calculated as:

$$Fuel\ Proportion\ (B - Double) = \frac{35 \times 745.56}{164{,}052.60}$$

$$Fuel\ Proportion\ (B - Double) = 15.91\%$$

The fuel consumption for each vehicle type, using the total fuel consumption value output by SIDRA, is shown by Equation 68.

Equation 68: Fuel consumption

$$Fuel\ Consumption(VT) = fuelcons(SIDRA) \times Fuel\ Proportion\ (VT)$$

Where:

- Fuelcons(SIDRA) = fuel consumption (L/hr) as per SIDRA output

Example: Fuel consumption

Fuel consumption for a B-double is:

$$Fuel\ Consumption(B - Double) = 100 \times 15.91\%$$

$$Fuel\ Consumption(B - Double) = 15.91\ L/hr$$

Morning peak fleet fuel consumption of 100 litres per hour equates to 15.91 litres per hour for a B-double.

Annual fuel cost for each vehicle type, using the weighted average fuel price (fuelcf) is shown by Equation 69.

Equation 69: Annual fuel cost

$$AnnualFuelCost(VT) = FuelCons(VT) \times \frac{Fuelcf}{100} \times PeriodPerYear \times HrsPerPeriod$$

Where:

- AnnualFuelCost(VT) = annual fuel cost per vehicle type
- FuelCons (VT) = fuel consumption per vehicle type (L/hr)
- Fuelcf = weighted fuel cost per vehicle type

Example: Annual fuel cost

In the B-double example, the annual fuel cost is calculated, assuming the weighted fuel cost for a B-double equals 81.57 cents per litre:

$$AnnualFuelCost(B - Double) = 15.91 \times \frac{81.57}{100} \times 260.90 \times 1$$

$$AnnualFuelCost(B - Double) = \$3385.10\, p.a$$

Table 36 shows the complete calculation of fuel costs in the morning peak using the previous intersection calculations.

Table 36: Intersection fuel cost example

Morning peak fuel cost						
Vehicle type	**Flow (veh/hr)**	**BFC (l/1000km)**	**Flow fuel consumption**	**Fuel proportion (%)**	**Fuel consumption (l/hr)**	**Annual fuel cost ($)**
Cars – private	700.00	96.40	67 480.50	41.13	41.13	8 852.59
Cars – commercial	100.00	140.92	14 091.50	8.59	8.59	1 848.63
Non-Articulated	100.00	239.97	23 996.87	14.63	14.63	3 130.53
Buses	5.00	239.97	1 199.84	0.73	0.73	156.18
Articulated	50.00	445.52	22 275.92	13.58	13.58	2 892.99
B-double	35.00	745.56	26 094.53	15.91	15.91	3 385.10
Road train 1	10.00	891.34	8 913.45	5.43	5.43	1 156.29
Road train 2	-	1 335.21	-	0.00	0.00	0.00
Total	1 000.00	4 134.89	164 052.60	100.00	100.00	21 422.30

8.3.3 Accident cost calculation

Accident costs for intersection evaluations are manually entered by the system user on a yearly basis. The manual calculation of accident costs can be derived using the formulae provided in Section 6.

Note: Average intersection crash costs per million vehicles entering an inter (MVE) are provided in Appendix F as per Austroads (2001) AP-R/184.

Example: Intersection accident

The crash cost for 1000 vehicles using the intersection with an average accident cost of $229 145 as per Section 6 is derived by the following:

$$CrashCost_{RT} = MVE \times A_{TR} \times AAcc_{RT}$$

$$CrashCost_{RT} = \frac{1000 \times 365.25 \times 1}{1.000.000} \times 0.25 \times \$229{,}145$$

$$CrashCost_{RT} = 0.36525 \times 0.25 \times 229{,}145$$

$$CrashCost_{RT} = \$20{,}924/\mathrm{year}$$

In this example a project specific crash rate has been adopted based on the accident history of the intersection.

8.3.4 Benefit calculation

Calculation of benefits derived from an intersection evaluation using the outputs from SIDRA in CBA6 is shown by Equation 70.

Equation 70: Total benefit

$$TotalBenefit = (TotalBaseCosts) - (TotalProjectCosts)$$

Where:

- TotalBaseCosts = Base delay costs + base fuel costs + base accident costs
- Total project Costs = Project delay costs + project fuel costs + project accident costs

Calculations of benefits are completed for each year of the evaluation in both the base and project cases. Where SIDRA data is only provided in the first and last year of the evaluation, intermittent data sets are interpolated through Equation 71.

Equation 71: Linear intersection interpolation

$$Value_{YrZ} = Value_{YrX} + (YrZ - YrX) \times \left(\frac{Value_{YrY} - Value_{YrX}}{YrY - YrX}\right)$$

Where:

- $Value_{YrZ}$ = value of the interpolated variable in a year for which data has not been provided
- $Value_{YrX}$ = value of the first variable provided by the data
- $Value_{YrY}$ = value of the second variable provided by the data

Note: Data can be entered for each individual year, although this will first require multiple runs of SIDRA.

8.4 Overtaking lanes

Overtaking lane methodology takes into account recent research on accident reductions from the Austroads report AP-R184. Reduction in crashes depends on the type of overtaking lane constroad user coststed. The methodology applied to the calculation of the reduction of crashes is different than the methodology applied to the calculation of the reduction of crashes of a standard road evaluation.

8.4.1 Travel time costs and vehicle operating costs calculation

The capacity of the downstream section is assumed to increase by 20% because of the constroad user coststion of the overtaking lane. Length of the downstream and upstream areas is assumed to be 5 km and 3 km respectively. For more information on the downstream and upstream areas, see Section 2.4.5 of the *Theoretical Guide*.

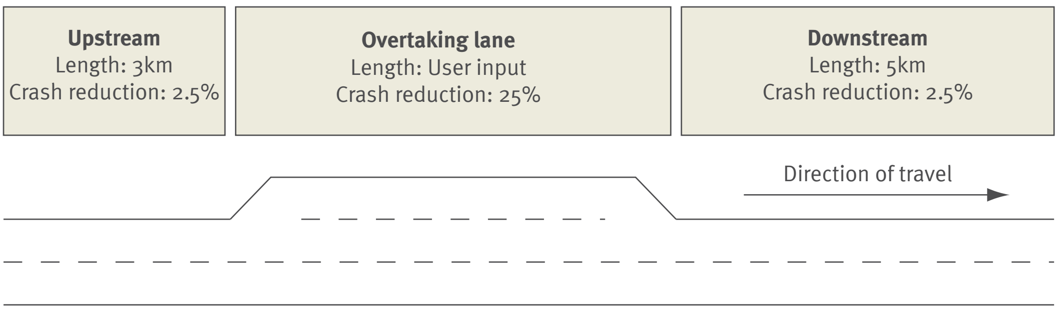
8.4.2 Crash costs

Provision of an overtaking lane will reduce the frequency of crashes for the road sections immediately before, during and after the overtaking lane location (Austroads 2001). Crash cost reduction for the three types of overtaking lanes is shown by Sections 8.4.2.1 to 8.4.2.3 of the *Theoretical Guide*.

8.4.2.1 Single overtaking lane

The crash cost reduction for a single overtaking lane is illustrated by Figure 7.

Figure 7: Single overtaking lane



Calculations for crash reductions are specified in monetary terms for a single overtaking lane by Equation 72. Accidents are reduced by 25% in the section where the overtaking lane is constroad user coststed, 2.5% in the 3 km upstream section and 2.5% in the 5 km downstream area. These reductions are applied to Equations 72 to 74.

Equation 72: Single overtaking lane crash reduction

$$ReductionOTL_{Single} = [(0.25 \times SecLength)A_R \times AADT \times 365.2 \quad \times 10^{-6}] \times Av.Crash\ Cost$$

$$ReductionUP_{Single} = [(0.025 \times 3)A_R \times AADT \times 365.25 \times 10^{-6}] \times Av.Crash\ Cost$$

$$ReductionDN_{Single} = [(0.025 \times 5)A_R \times AADT \times 365.25 \times 10^{-6}] \times Av.Crash\ Cost$$

Where:

- $\text{ReductionOTL}_{\text{Single}}$ = reduction in crashes for the overtaking section

- ReductionUP$_{Single}$ = reduction in crashes for the upstream section
- ReductionDN$_{Single}$ = reduction in crashes for the downstream section
- A_R = base case crash rate for the relevant section (crashes per MVKT)
- SecLength = length of the relevant section (km)

Example: Single overtaking lane crash reduction

The reduction in crashes for a 2 km overtaking lane on a highway with MRS of 12 and 1000 vehicles is calculated by:

$$ReductionOTL_{Single} = [(0.25 \times 2)0.281690141 \times 1000 \times 365.25 \times 10^{-6}] \times 229{,}145$$

$$ReductionOTL_{Single} = \$11{,}788.06$$

$$ReductionUP_{Single} = [(0.025 \times 3)0.281690141 \times 1000 \times 365.25 \times 10^{-6}] \times 229{,}145$$

$$ReductionUP_{Single} = \$1768.21$$

$$ReductionDN_{Single} = [(0.025 \times 5)0.281690141 \times 1000 \times 365.25 \times 10^{-6}] \times 229{,}145$$

$$ReductionDN_{Single} = \$2947.01$$

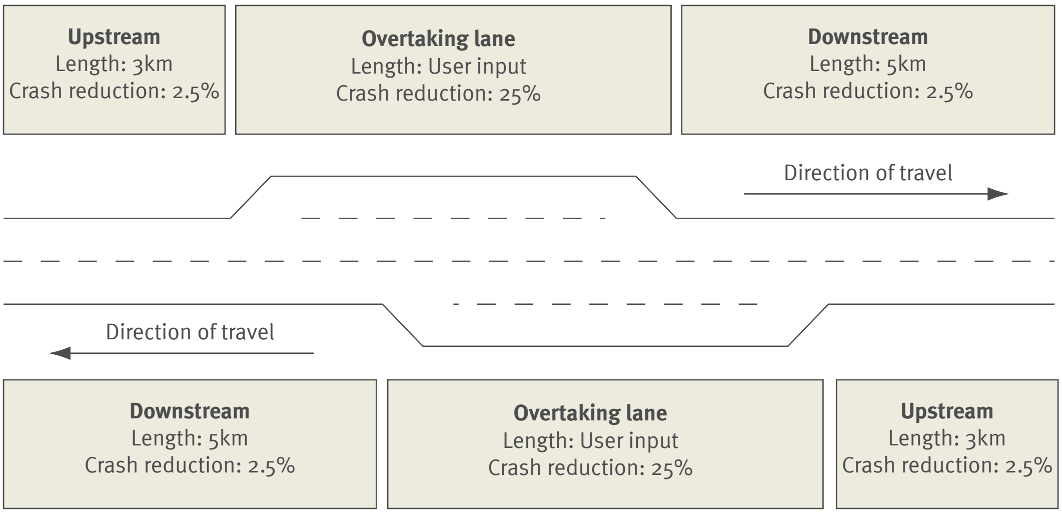
Crash cost reduction is the sum of the single, upstream and downstream overtaking lane sections. The total crash cost reduction as a result of the overtaking lane above is equal to $16 503.28.

Note: The difference between the upstream and downstream benefits is a factor of the section length.

8.4.2.2 Head-to-head overtaking lane

The crash reduction of a head-to-head overtaking lane is illustrated by Figure 8.

Figure 8: Head-to-head overtaking lane



Equations for calculating the crash cost reduction for a head-to-head overtaking are shown by Equation 73.

Equation 73: Head-to-head overtaking lane accident reduction

$$ReductionOTL_{hth} = [0.25(2 \text{ x SecLength - SS})A_R \text{ x AADT x } 365.25 \text{ x } 10^{-6}] \text{ x AvCrashCost}$$

$$ReductionUP_{hth} = [(2 \text{ x } 0.025 \text{ x } 3)A_R \text{ x } AADT \text{ x } 365.25 \text{ x } 10^{-6}] \text{ x } AvCrashCost$$

$$ReductionDN_{hth} = [(2 \text{ x } 0.025 \text{ x } 5)\ A_R \text{ x } AADT \text{ x } 365.25 \text{ x } 10^{-6}] \text{ x } AvCrashCost$$

Where:

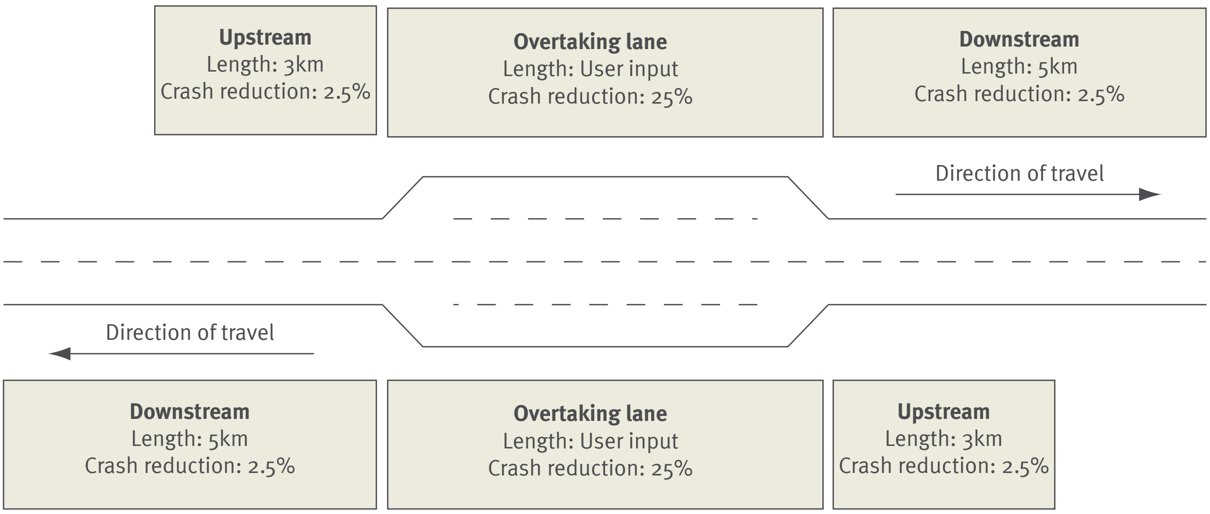
- $ReductionOTL_{hth}$ = reduction in crashes for the overtaking section
- $ReductionUP_{hth}$ = reduction in crashes for the upstream section
- $ReductionDN_{hth}$ = reduction in crashes for the downstream section
- A_R = base case crash rate for the relevant section (crashes per MVKT)
- SecLength = length of the relevant section (km)
- SS = section length of the overtaking lane that runs side-by-side

Note: Unlike single overtaking lanes, accident reductions for head-to-head overtaking lanes are derived from two upstream and downstream areas.

8.4.2.3 Side-by-side overtaking lane

Equations for calculating the crash cost reduction for a side-by-side overtaking lane are shown by Equation 74. Figure 9 illustrates the crash reduction of a side-by-side overtaking lane.

Figure 9: Side-by-side overtaking lane



Equation 74: Side-by-side overtaking lane accident reduction

$$ReductionOTL_{sbs} = [(0.25 \text{ x } SecLength)A_R \text{ x } AADT \text{ x } 365.25 \text{ x } 10^{-6}] \text{ x } AvCrashCost$$

$$ReductionUP_{sbs} = [(2 \text{ x } 0.025 \text{ x } 3)A_R \text{ x } AADT \text{ x } 365.25 \text{ x } 10^{-6}] \text{ x } AvCrashCost$$

$ReductionDN_{sbs}$ = [(2 x 0.025 x 3)A_R x $AADT$ x 365.25 x 10^{-6}] x $AvCrashCost$

Where:

- $ReductionOTL_{sbs}$ = reduction in crashes for the overtaking section
- $ReductionUP_{sbs}$ = reduction in crashes for the upstream section
- $ReductionDN_{sbs}$ = reduction in crashes for the downstream section
- AR = base case crash rate for the relevant section (crashes per MVKT)
- SecLength = length of the relevant section (km)

Note: The side-by-side overtaking lane is not expected to provide the same amount of safety benefits when compared to the head-to-head overtaking lane. The side-by-side configuration is usually constroad user coststed over a shorter 'net' distance. For example, the head-to-head overtaking lane can be constroad user coststed as two separate overtaking lanes at 3 km each, which equates to 6 km in total, whereas two side-by-side overtaking lanes, 3 km each, only accounts for 3 km in total road section.

8.5 Generated traffic

As discussed in Section 2.4.2 of the *Theoretical Guide*, generated traffic is the number of additional road users making trips in the project case. The benefits of generated traffic can be illustrated by the increase in consumer surplus in Figure 10.

Figure 10: Generated traffic

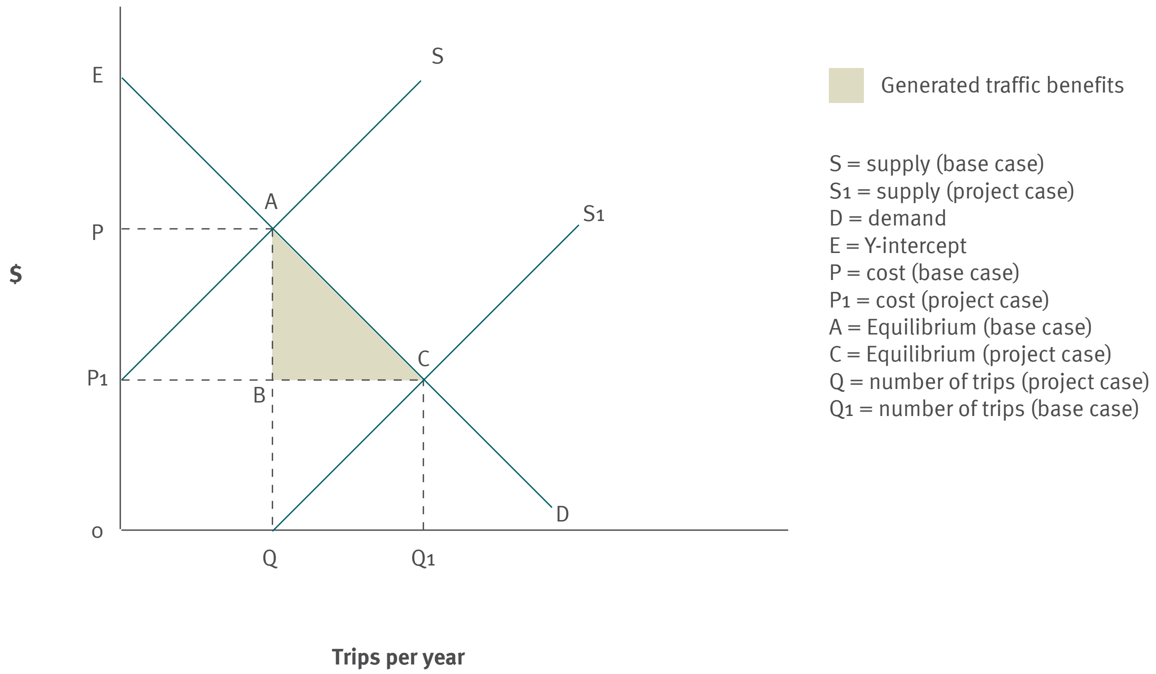


Figure 10 shows that when road user costs decline from p to p1, the declining perceived cost per trip entices more trips to be made by transport and generates additional road users. The declined perceived cost per trip is a result of an improvement in the quality of the road. The benefit accruing to those generated road users is measured by the triangle, ACB. The generated traffic module in CBA6 measures the benefit represented by this triangle by applying 'the rule of half'.

Note: The theory of generated traffic benefits should not be applied to an evaluation with a capacity constraint issue.

The generated traffic benefit calculation is given by Equation 74. This equation applies the 'rule of half' to calculate the benefits of increased road use by incorporating the benefits of lower TTC and VOC.

Equation 75: Generated traffic

$$Benefits_{GENTRAF} = \frac{\left(\left((TTC_{BC} + VOC_{BC}) - (TTC_{PC} + VOC_{PC})\right) \times GenTraffic\right)}{2}$$

Where:

- $Benefits_{GENTRAF}$ = the total value of generated traffic benefits derived in CBA6 ($)
- GenTraffic = the number of vehicles generated from a project (vehicles)
- TTC_{BC} and VOC_{BC} = base case annual total road user cost per vehicle
- TTC_{PC} and VOC_{PC} = project case annual total road user cost per vehicle

Note: Total road user costs (TTC and VOC) are calculated as follows:

$$RUC = \frac{Sec\ Length \times Unit\ RUC \times 365.25}{100}$$

Example: Generated traffic

Table 37 outlines a generated traffic example which shows that an upgrade of a 5 km section of road offers a significant reduction in travel cost which in turn is expected to generate 50 extra trips made by private vehicles. Using the data in Table 37 and Equation 75, the benefit from generated traffic is:

$$Benefit_{GENTRAF} = \frac{\big((253.85 + 279.42) - (228.25 + 255.68)\big) \times 50)}{2}$$

$$Benefit_{GENTRAF} = \$1232.72\ p.a$$

The above calculations show that the economic benefit of an increase in the number of private vehicles is $1233 where the benefit to existing road users is $4930.

Table 37: Generated traffic (private vehicle)

Case	Section length (km)	TTC (c/km)	VOC (c/km)	TTC per vehicle ($ p.a)	VOC per vehicle ($ p.a)	AADT	Generated vehicles	Annual existing benefit	Annual generated benefit ($)
Base	5	13.9	15.3	253.85	279.42	100	50	4 930.88	1 232.72
Project	5	12.5	14.0	228.28	255.68	150			

8.6 Livestock damage

Damage to livestock occurs as a result of dust inhalation and jarring on unpaved or unsealed roads. Livestock damage benefits are calculated using default values from Table 38. This table shows that the default livestock benefit is based on the change in MRS between the base and project cases. For example, if the base case road has an MRS of 1 (unsealed natural surface) and the road is upgraded to an MRS of 3 (paved ‹ 4.5 m), the benefit per kilometer for a B-double is $0.605.

The largest livestock benefit accrues when an unsealed/formed road is upgraded to a sealed surface in the project case. The lowest benefits occur when a paved road is sealed.

Table 38: Damage to livestock benefits

Heavy vehicle type	Benefits ($/km)		
	Unsealed/formed road to sealed road	Unsealed/formed road to gravel/paved road	Paved road to sealed road
	MRS 1, 2 to MRS 5+	MRS 1, 2 to MRS 3,4	MRS 3,4 to MRS 5+
Articulated	0.304	0.202	0.104
B-double	0.909	0.605	0.304
Road train 1	0.909	0.605	0.304
Road train 2	0.909	0.605	0.304

Source: TMR, see Appendix I – model road state.

The proportion of heavy vehicles carrying livestock requires specification in order for CBA6 to calculate the livestock damage benefits. Equation 76 can be used to determine the proportion of total vehicles carrying livestock.

Equation 76: Vehicles carrying livestock

$$\%Livestock(VT) = \frac{VT_{Livestock}}{VT_{Total}}$$

Example: Vehicles carrying livestock

The AADT along an unsealed paved road is 200 and there are approximately 20 B-doubles, with only five of the 20 B-doubles carrying livestock.

$$\%Livestock(B - Double) = \frac{5}{20} = 25\%$$

25% would be entered in the livestock column for B-doubles.

After the proportion of vehicles carrying livestock has been determined, the benefits that are attributable to these vehicles can be calculated using Equation 77. This shows the annual livestock damage benefit for those heavy vehicles carrying livestock based on the road upgrade benefit from Table 38.

Equation 77: Annual livestock benefits

$$Benefits_a = \sum_{VT} Benefit_{i(VT)} \times AADT(VT) \times Livestock_c\%(VT) \times 365.25 \times SecLength$$

Example: Annual livestock benefits

Table 39 illustrates the calculation of livestock benefits for a 10 km upgrade from an unsealed road with an MRS 4, to a sealed road with an MRS 7. By inputting the assumed data presented in Table 39 into Equation 77, the benefits per year by vehicle type can be calculated. The results of these calculations are shown in the 'benefits/year' column of Table 39.

Table 39 shows that a benefit of $0.304 per kilometre per vehicle, for 35 B-double vehicles, travelling 10 km, on a road upgraded from an unsealed road with an MRS of 4 to a sealed road with an MRS of 7, is equivalent to a benefit of $31 724.

Table 39: Damage to livestock benefits example

Vehicle type	Benefits ($/km)	Section length (km)	Number of vehicles	Breakdown (%)	Number carrying livestock	Livestock (%)	Benefits/year ($)
Cars – private	-	10	700	70.0	-	-	-
Cars – commercial	-	10	100	10.0	-	-	-
Non-Articulated	-	10	100	10.0	-	-	-
Buses	-	10	5	0.5	-	-	-
Articulated	0.104	10	50	5.0	20	40.0%	15 194.40
B-double	0.304	10	35	3.5	10	28.6%	31 724.57
Road train 1	0.304	10	10	1.0	2	20.0%	22 207.20
Road train 2	0.304	10	0	0.0	0	-	-
Total	-	10	1000	100	32	-	69 126.17

8.7 Bypass

A bypass is a new road which provides an alternative route for traffic around a town or built-up area. In a bypass, the total costs of all individual links are compared with a proposed bypass. Evaluations of bypasses tend to be data intensive depending on the magnitude of the bypass. For an example of a bypass, see Section 5.7 of the *User Guide*.

In terms of methodology, CBA6 compares total road user costs on all individual links and the proposed bypass. The bypass benefit calculation is shown by Equation 78.

Equation 78: Bypass

$$BypassBenefits = (RUC1_{BC} + RUC2_{BC} + \ldots RUCB_{BC}) - (RUC1_{PC} + RUC2_{PC} + \ldots RUCB_{PC})$$

Where:

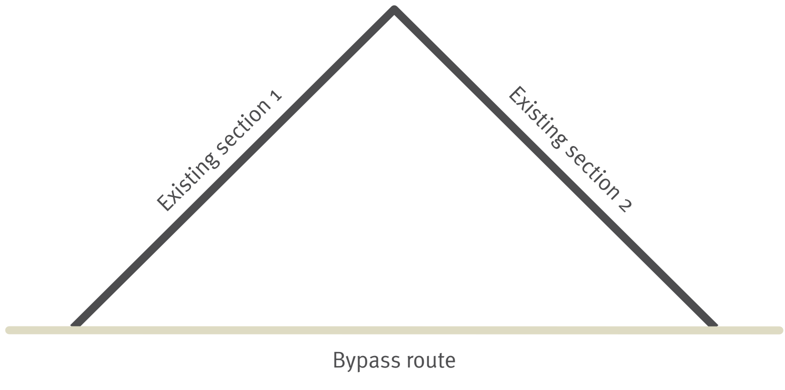
- Road user costs1_{BC} = base case road user costs for existing section 1
- Road user costs1_{PC} = project case road user costs for existing section 1
- Road user costsB_{BC} = base case road user costs for the bypass section

Note: Road user costs1_{BC} = (TTC_{BC} + VOC_{BC} + Acc_{BC}).

Road user costs are calculated based on road conditions and traffic volume for each individual road link and bypass section for both base and project cases. The calculation of road user costs for each existing road section and bypass section is consistent with the TTC, VOC and accident costs shown previously in Sections 4 to 6.

An example of a bypass project is shown by Figure 11 and Table 40. This example shows that without the bypass, road users only have the option of travelling along the existing sections. Once the bypass route is in place, some motorists who travel through the town will opt not to travel along the existing sections but alternatively choose to travel on the bypass route.

Figure 11: Bypass



To calculate the traffic breakdown of a bypass, attention is given to the amount of vehicles which divert from the existing sections to the bypass in a project case. For example, in the bypass case study shown in the *User Guide*, the breakdown is shown by Table 40.

Table 40: Bypass traffic breakdown example

	Existing 1		Existing 2		Existing 3		Existing 4		Bypass	
	Base	Project	Base	Project	Base	Project	Base	Project	Base	Project
AADT	4 000	2 000	8 000	6 000	8 000	6 000	4 000	2 000	0	2 000
Cars – private	82.0%	88.0%	82.0%	84.0%	82.0%	84.0%	82.0%	84.0%	0.0%	76.0%
Cars – commercial	11.0%	9.0%	11.0%	10.3%	11.0%	10.3%	11.0%	10.3%	0.0%	13.0%
Non-Articulated	3.3%	1.6%	3.3%	2.7%	3.3%	2.7%	3.3%	2.7%	0.0%	5.0%
Buses	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	0.0%	1.0%
Articulated	1.1%	0.2%	1.1%	0.8%	1.1%	0.8%	1.1%	0.8%	0.0%	2.0%
B-double	1.6%	0.2%	1.6%	1.1%	1.6%	1.1%	1.6%	1.1%	0.0%	3.0%
Road train 1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Road train 2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Growth rate (%pa linear)	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	N/A	3.0%

To estimate the project case vehicle breakdown, the number of vehicles that enter the bypass in the project case is derived from each existing section's breakdown, and is shown by Table 41.

Table 41: Bypass example – average annual daily traffic

	Existing 1		Existing 2		Existing 3		Existing 4		Bypass	
	Base	Project	Base	Project	Base	Project	Base	Project	Base	Project
AADT	4 000	2 000	8 000	6 000	8 000	6 000	4 000	2 000	-	2 000
Cars – private	3 280	1 760	6 560	5 040	6 560	5 040	3 280	1 680	-	1 520
Cars – commercial	440	180	880	620	880	620	440	207	-	260
Non-Articulated	132	32	264	164	264	164	132	55	-	100
Buses	40	20	80	60	80	60	40	20	-	20
Articulated	44	4	88	48	88	48	44	16	-	40
B-double	64	4	128	68	128	68	64	23	-	60
Road train 1	-	-	-	-	-	-	-	-	-	-
Road train 2	-	-	-	-	-	-	-	-	-	-

The number of vehicles which will divert to the bypass is the difference between the bypass project case and each existing section base case, as given by Equation 79.

Equation 79: Existing project case AADT

$$Existing_x\ AADT_{PC}(VT) = Existing_x\ AADT_{BC}(VT) - Bypass_{PC}AADT(VT)$$

Example: Existing project case AADT

In the bypass case study, AADT for the existing 1 for private cars is calculated as follows:

$$Existing\ 1\ AADT_{PC}(Private) = 3280 - 1520 = 1760$$

Existing private car AADT is converted to a percentage of total AADT.

$$Existing\ 1\ AADT_{PC}\%\ (Private) = \frac{1760}{2000} * 100 = 88\%$$

Example: Bypass

Referring to Figure 11, a single B-double is currently travelling along two individual 10 km links (existing Sections 1 and 2), which will be bypassed under a new project. The single B-double is assumed to divert to the 7 km new bypass route. The aggregate discounted road user costs for the individual links are assumed to be $525 000 and $650 000 for existing Sections 1 and 2 respectively. When the bypass road is completed, the B-double is assumed to incur net discounted road user costs equal to $750 000 for travelling along the bypass route. The total benefit of the bypass project is:

$$BypassBenefits = (525{,}000 + 650{,}000 + 0) - (0 + 0 + 750{,}000)$$

$$BypassBenefits = \$425{,}000$$

The above calculation shows that in the base case, the B-double only incurs road user costs for the existing Sections 1 and 2 as there are no road user costs for the bypass route in the base case, because the bypass route is assumed to be a new road (i.e. there is no bypass route in the base case).

However, in some instances the bypass route could be an existing road. This example also shows that in the project case the B-double only travels on the bypass route.