SAVi Sustainable Asset Valuation

A Sustainable Asset Valuation of a Road Infrastructure Project in Queensland, Australia

IISD International Institute for Sustainable Development

RESILIENT FUTURES INVESTMENT ROUNDTABLE

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About the Resilient Futures Investment Roundtable

Resilient Futures Investment Roundtable (RFIR) is a group of private, public, research, and not-for-profit organizations collaborating to improve the way that the costs and benefits of resilience are valued to create better public and private resilience investment decisions. The aim of the RFIR is to increase the flow to investment to resilience-building projects by supporting organizations to make informed, future-proofed decisions about when, where, and how to invest in resilience.

The RFIR is developing practice cases and guidance materials to enable systemic, risk-informed investment decision making that enhances resilience to climate and disaster hazards. As a member of the Initiative, Queensland Reconstruction Authority (QRA) has been sharing insights and learnings from undertaking resilience valuation as part of the Queensland Betterment program.

A case study was developed for the RFIR that considered QRA's cost-benefit analysis of betterment projects, focusing on the 2013 upgrade to the Gayndah Water Supply Intake Station in North Burnett Regional Council. This was a retrospective cost-benefit analysis comparing the restoration costs with avoided costs from extreme events that have impacted the infrastructure since it was rebuilt. This cost-benefit analysis demonstrated that avoided costs exceeded reconstruction and restoration costs much faster than expected with the Gayndah Water Supply Intake Station remaining functional throughout all subsequent natural disaster events.

A tailored SAVi tool is now enabling QRA to explore the expansion of the initial cost-benefit analysis of betterment projects to capture some of the direct and indirect economic, social, and environmental outcomes of investments in building infrastructure back to a more resilient standard. The experiences, learnings, and insights from this process will be developed by the RFIR into a practice case and guidance materials.

The new analysis has considered a wide range of benefits, using 15 indicators that include road disruption, access to services, market access for crops, fruit, and livestock, and pollution, including air, noise, and water. This holistic approach has been applied retrospectively to a sample of betterment projects to understand the full benefits that investments in resilient infrastructure can generate. This will also be used to inform future resilience investment decisions in infrastructure resilience by drawing on available data and information to predict future impacts on infrastructure and determine which projects would be most beneficial in strengthening overall community resilience.

For more information on SAVi: www.iisd.org/savi

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1.0 Overview

This document describes the methodology used to estimate the direct, indirect, and induced economic, social, and environmental outcomes of investing in road infrastructure resilience in the state of Queensland, Australia.

The International Institute for Sustainable Development has worked with the Queensland Reconstruction Authority (QRA) to develop an Excel-based cost-benefit analysis (CBA) model to undertake an economic and financial assessment of betterment road infrastructure projects that consider intangible benefits of investments in infrastructure resilience. When considering betterment investments, the model offers an estimation of past social, economic, and environmental benefits of improved climate resilience to understand current benefits as well as benefits into the future. As a result, this work complements the analysis already carried out as part of the Betterment Program, which focuses on the direct, road-related avoided costs of betterment investments.

This document primarily identifies and presents a variety of impacts of road disruption, a method for their quantification, both in physical and economic terms, and the mathematical model created to perform an integrated CBA of betterment investments.

The proposed method and model support the estimation of the financial internal rate of return (IRR), net present value (NPV), and benefit-to-cost ratio (BCR) of investments in road resilience. Results also include an economic analysis that considers the economic valuation of several socio-economic and environmental non-road benefits, which are not considered in financial assessments. As a result, two versions of the IRR, NPV, and BCR are provided to directly compare the financial and economic assessments, and clearly highlight the contribution of indirect and induced social and environmental outcomes of road resilience investments.

The application of the model to case studies has highlighted the magnitude and relevance of indirect and induced non-road benefits. This confirms the importance of considering the indirect and induced social, economic, and environmental outcomes of road resilience investments, in addition to the direct economic benefits these generate (e.g., avoided costs of reconstruction due to climate impacts). This is particularly important for future investments aimed at improving the road network in a proactive manner (i.e., before climate-related damage occurs), in addition to informing decision making on reconstruction (post climate impact).

2.0 Introducing CBA and Related Indicators

A CBA is a "pre-investment tool" that can be used to help inform investment decisions. Since the costs and benefits of investments often do not occur at the same time, with costs usually preceding benefits, the comparison is not always straightforward. The CBA provides indicators to support decision making as well as suggesting the best alternatives for different stakeholders, allowing the comparison of projects using the same underlying framework of analysis to determine which ones provide the most value for money across tangible and intangible benefits.

The CBA provides a variety of results, including:

- An estimation of the total costs and benefits of a project. This information is provided over the lifetime of the project, with annual time steps. Annual results can be added over time to provide an assessment of the cumulative benefits of the investment.
- A variety of indicators that can be estimated to assess the overall performance of the investment. Three main indicators are commonly used: the IRR, NPV, and BCR.

NPV

The NPV is the difference between the present value of cash inflows (discounted value of tangible flows for the investor) and the present value of cash outflows.

IRR

The IRR is an indicator that can be used to determine whether there is a profitable return on investment. The IRR is considered as a discount rate bringing the NPV of all cash flows to zero (in a discounted cash flow analysis). Generally, a higher IRR denotes a more desirable investment and therefore can be used to compare investment options.

BCR

The BCR considers both the costs and the benefits of an investment. While NPV and IRR consider cash flows, the BCR shows the relationship between costs and benefits of the project or investment. When or if an investment offers a BCR greater than 1, it generates more benefits than costs, and it is expected to deliver a positive NPV.

To capture the full range of outcomes generated by a certain investment, the model has pushed the boundaries of traditional CBAs, going beyond direct costs and benefits. The CBAs presented in this study can be considered "integrated" or "extended" in that they also include an economic valuation of indirect and induced project outcomes, often labelled as "externalities." As a result, the integrated CBA proposed for this assessment is broad in nature, as it includes indicators that are of relevance to the project (e.g., betterment investment and avoided reconstruction cost due to improved climate resilience to future disaster events) as well as to society (e.g., avoided cost resulting from the need to travel longer distances, reduced access to markets and public services, as well as mental health costs), even if these are not directly connected to the investment and its performance. Therefore, the CBA generated with the model proposed estimates the societal value of the betterment investment.

To capture both investment-related and societal impact indicators, the model offers multiple estimations of the IRR, NPV, and BCR. The first (a financial assessment) includes only the direct impacts of the investment stream. The second (an economic assessment) includes all avoided costs and non-road benefits. This means the model is able to easily determine the net contribution of betterment investments (as opposed to conventional reconstruction) to society.

3.0 Formulating an Integrated CBA

The CBA includes both upfront investment and resulting avoided costs and added benefits. Data on the investment required were obtained from the information collected for each betterment project; for future projects, the investment required would need to be estimated. Concerning the non-road avoided costs and added benefits, a literature review was performed on methods for economic valuation. The model proposed allows us to (i) modify the coefficients used for the economic valuation, (ii) select or de-select indicators of relevance for the economic analysis (e.g., only a subset of the indicators considered would be relevant in an urban context) and (iii) add new indicators should there be a need to further customize the model to capture local specificities.

More specifically, to fill the information gap on the additional avoided costs and benefits resulting from betterment investments, a literature review was carried out, coupled with an assessment of local dynamics, for 10 selected case studies (Table 1). This analysis has allowed for the identification of the most common avoided costs and added benefits generated by betterment investments in Queensland for their quantification and inclusion in the integrated CBA (Table 2).

Table 1. Summary of cost information collected from the 10 betterment case studies

Case study #	Name of the case study	Type of intervention	Unit value	Unit[1]	Notes
1	Aurukun Access Road, Aurukun Shire Council	**Bitumen sailing**			
		Damage cost	N/A	$/Km	
		Restoration	87,300	$/Km	10 km considered
		Betterment	109,241	$/Km	10 km considered
		Avoided cost	840,777	$	Divided by 8 (avoided disaster events)
2	Gayndah Mundubbera Road, North Burnett Regional Council	**Stormwater drainage**			
		Damage cost	N/A	$/Km	
		Restoration	3,392,854	$/Km	2 km considered
		Betterment	654,432	$/Km	2 km considered
		Avoided cost	6,785,707	Km	Divided by 4 (avoided disaster events)

[1] All units in AUD unless otherwise indicated.

Case study #	Name of the case study	Type of intervention	Unit value	Unit[1]	Notes
3	**Villis Bridge – Scenic Rim Regional Council**	**Safer concrete and stream bank protection**			
		Damage cost	N/A	$/m	
		Restoration	26,618	$/m	60 m considered
		Betterment	3,881	$/m	60 m considered
		Avoided cost	1,597,077	$	Divided by 4 (avoided disaster events)
4	**Gayndah Water Intake - North Burnett Regional Council**	**Water intake relocation**			
		Damage cost	1,200,000	$	
		Restoration	2,704,360	$	
		Betterment	925,110	$	
		Avoided cost	2,704,360	$	Divided by 4 (avoided disaster events)
5	**Upper Mount Bentley Road – Palm Island Aboriginal Shire Council**	**From gavel road to concrete**			
		Damage cost	550	$/m	500 m considered.
		Restoration	717	$/m	500 m considered
		Betterment	878	$/m	500 m considered
		Avoided cost	358,447	$	Divided by 5 (avoided disaster events)
6	**Inverdon Bridge – Whitsunday Regional Council**	**Concrete bridge with reduced risk of overtopping by floodwaters and with the capacity to withstand greater debris loading**			
		Damage cost	N/A		
		Restoration	5,298,051	$	
		Betterment	837,385	$	
		Avoided cost	5,298,051	$	Divided by 2 (avoided disaster events)

Case study #	Name of the case study	Type of intervention	Unit value	Unit[1]	Notes
7	**Weipa-Mapoon Road – Mapoon Aboriginal Shire Council**	**Bitumen sealing including drainage works**			
		Damage cost	102,564	$/Km	7.8 km considered. 2 disaster events
		Restoration	121,286	$/Km	7.8 km considered
		Betterment	99,485	$/Km	7.8 km considered
		Avoided cost	946,028	$	Divided by 6 (avoided disaster events)
8	**Richmond Road – Croydon Shire Council**	**Bitumen sealing three gravel sections and cement-stabilizing two gravel sections of the road**			
		Damage cost	275,000	$/Km	
		Restoration	1,648,270	$	
		Betterment	1,800,249	$	
		Avoided cost	1,642,836	$	Divided by 6 (avoided disaster events)
9	**Oak Park Road – Etheridge Shire Council**	**Reinforced concrete boxed culverts to raise the level of the approaches and increase the flow capacity**			
		Damage cost	N/A	$/m	
		Restoration	9,121	$/m	51m considered
		Betterment	12,420	$/m	51 m considered
		Avoided cost	465,153	$	Divided by 6 (avoided disaster events)

Case study #	Name of the case study	Type of intervention	Unit value	Unit[1]	Notes
10	Cloncurry Shire Council – Sedan Dip Road betterment works	**Sealed pavement to strengthen the resilience to the previously unsealed section**			
		Damage cost	N/A	$/Km	
		Restoration	9,403,483	$	31 km considered
		Betterment	1,138,005	$	31 km considered
		Council contribution	494,867	$	31 km considered
		Avoided cost	N/A	$	

3.1 Investment Required, Betterment Costs

The Betterment Case Studies on QRA's webpage provides information on the infrastructure damage costs, restoration costs, and betterment investment, and road costs that have already been experienced and avoided. This information was extracted for 10 case studies and organized in a way that allows for a comparison across projects, expressing the cost in AUD/km or AUD/metre. Different investment types have been targeted to demonstrate a comprehensive view of the cost of different types of reconstruction and betterment activities.

3.2 Non-Road Damages and Benefits

This paper identified issues resulting from road damage for each of the 10 case studies analyzed. A total of 15 distinct issues are identified here (outlined in Table 2), which can also be considered non-road benefits of betterment projects (e.g., the indirect benefits of investing in infrastructure resilience).

These issues include:

- Road disruption, meaning extra time and fuel costs to reach a destination when the road normally used is damaged.
- Additional air and noise pollution generated by the diversion of passenger and freight vehicles.
- Reduced access to markets (e.g., crops, meat, and fish).
- Reduced access to services (e.g., schools and health care facilities).
- Mental health impacts.

Table 2. Identified issues and proposed methodology to quantify them (see Section 4 for more details)

	Issue identified	**CS 1**	**CS 2**	**CS 3**	**CS 4**	**CS 5**	**CS 6**	**CS 7**	**CS 8**	**CS 9**	**CS 10**	***Total***	**Proposed methodology for quantification**
1, 2, 3, 4	Road disruption may require to travel longer distances to commute to work and to perform other activities. Increases fuel and maintenance costs of vehicles and roads. Cost of travel time is also included.		X	X					X	X		4	Additional travel distance results in more energy use and hence higher energy costs, as well as in additional vehicle maintenance. We could estimate the additional energy use by multiplying the energy efficiency of a vehicle by the additional km driven. This is then multiplied by the market price of gasoline. Increased travel time also increases operation and maintenance (O&M) costs of roads and cars. These values have been retrieved from the literature.
5	Air pollution: the use of energy results in the creation of air pollution and causes harm to human health.		X	X					X	X		4	Additional travel distance results in more energy use and air emissions and pollution. This causes harm to human health and can be estimated as the economic cost of morbidity and mortality, per kg of air emissions created and based on local air pollution.
6	Noise pollution: the diversion of private vehicles and trucks to alternative roads is likely to increase noise pollution.		X	X					X	X		4	A specific noise factor (or cost factor) could be attributed to different types of vehicles per km driven. This would then be multiplied by the additional km driven due to road damage.

	Issue identified	CS 1	CS 2	CS 3	CS 4	CS 5	CS 6	CS 7	CS 8	CS 9	CS 10	*Total*	Proposed methodology for quantification
7	Water pollution: additional energy use in transport can increase the atmospheric deposition of N and other pollutants.		X	X					X	X		*4*	Additional travel distance results in more energy use and air emissions and pollution. Atmospheric deposition increases the amount and concentration of pollutants in water. A cost factor could be used and assigned to each additional km driven due to road disruption.
8	GHG emission: the use of energy results in the creation of GHG emissions and worsens climate change.		X	X					X	X		*4*	As above, we estimate additional energy consumption and GHG emissions. A cost factor could be used and assigned to each additional km driven due to road disruption.
9	Nature and landscape: harm to the environment and to economic activities (e.g., tourism).	X	X	X					X	X	X	*6*	Road disruption may prevent (or discourage) tourists from visiting local attractions. The average number of annual visitors could be used, reduced by the number of days that the road providing access is damaged.

	Issue identified	**CS 1**	**CS 2**	**CS 3**	**CS 4**	**CS 5**	**CS 6**	**CS 7**	**CS 8**	**CS 9**	**CS 10**	***Total***	**Proposed methodology for quantification**
10	Crop and fruit market access: road disruption may disrupt selling/exporting food to outside markets.	X	X	X	X	X	X	X	X	X		*9*	Road disruption may prevent producers from reaching markets or delay them from reaching them, which could affect market price and revenue generation. We estimate the amount of hectares in the proximity of the road damage, the production (based on land size and productivity), and the potential revenue (based on market price).
11	Fish market access: road disruption may not disrupt selling/exporting food to outside markets.	X				X	X	X				*4*	As in the case of crops, we estimate the amount of production capacity stranded because of road damage (e.g., based on the number of consumers that cannot be reached). We calculate the foregone revenue based on quantity of avoided consumption and market price.
12	Livestock a) Market access: road disruption may disrupt the selling/ trading of animals. b) Damage of dust inhalation and jarring on livestock and related decline in value.										X	*1*	a) As in the case of crops, we estimate the amount of revenues stranded because of road damage. We calculate the foregone revenue based on the reduction in animals traded. b) Damage to livestock occurs as a result of dust inhalation and jarring on unpaved or unsealed roads. Livestock damage figures are retrieved from the literature, by vehicle type.

	Issue identified	CS 1	CS 2	CS 3	CS 4	CS 5	CS 6	CS 7	CS 8	CS 9	CS 10	*Total*	Proposed methodology for quantification
13	Access to essential items/services: food, water, and medicine delivery may be impossible if the road is damaged.	X		X	X	X		X		X		*6*	Road disruption may prevent the delivery of critical services. We estimate the amount of population without access to such services, and the cost of delivery per person.
14	Access to workplace and schools: road disruption may make it impossible to reach the workplace (or schools, also affecting families and workers), resulting in reduced labour productivity.	X	X	X	X			X	X	X		*7*	When access to the workplace is not available, it can be assumed that labour productivity declines (at least for the portion of workers that cannot be work remotely). We could estimate the number of people impacted by road disruption that cannot reach the workplace (e.g., a percentage of the total number) and assume that they would not receive a salary for the days in which they cannot reach the workplace (based on an average monthly salary for the area).
15	Mental health: economic impact of psychological distress.	X			X	X		X	X	X		*6*	Natural disasters can lead to fatalities and injuries, and the traumatic nature of these events can lead to long-standing impacts on mental and physical health. By calculating the economic impact of phycological distress per person from case studies, we estimate the total economic impact of a given road damage event.

A close look at the issues presented in Table 2 shows that these are many and varied, they affect different economic actors, and not all are tangible (i.e., not all result in cash inflow or outflow). Table 3 offers more details related to the nature of the impact assessed (i.e., whether it is tangible or intangible) and in relation to the type of actor impacted (i.e., businesses vs. people).

For example, concerning the type of impact considered, access to markets is a tangible impact. Reduced delivery of crops, meat, and fish to the market may result in reduced revenues for producers. This is particularly the case for fresh fruits and vegetables, fresh meat, and fish. Certain types of production are not impacted, such as grains and processed and frozen products, all of which can be stored for longer periods of time. The increased costs of fuel and operation and maintenance of vehicles and roads (those that are used more intensively due to diversions) are also tangible, in that they result in cash outflows for people and businesses (cost of fuel and vehicles) and for the government (road maintenance).

All other indicators are instead intangible, in that they do not affect cash flows. Nevertheless, these indicators are relevant and can be estimated economically. For instance, the cost of time may be considered to be tangible for businesses that operate in the delivery sector. On the other hand, for people time is not monetized (e.g., if there is more traffic in the morning to reach the office, departure from home may be impacted). While the reduction of time available for other activities is an undesirable impact of road disruption, it does not imply a cash outflow. As a result, this impact is considered intangible and offers an economic valuation (e.g., the opportunity cost of using time differently) that is included in the integrated CBA, as part of the non-road benefits of the betterment investment. A similar approach is followed for other non-road benefits, including air, noise, and water pollution, GHG emissions, impacts on nature and landscape, as well as on access to services and mental health. In other words, an attempt has been made to estimate the economic value of both tangible and intangible impacts to perform a societal assessment to take a more holistic view of the benefits of investing in infrastructure resilience.

Table 3. Non-road impacts, interpreted in relation to the type of impact and the economic actors impacted

	Type of impact		Who is impacted		
Indicators	**Tangible**	**Intangible**	**Businesses**	**People**	**Comments**
1 Cost of fuel	X		X	X	The cost of fuel use increases if the distance to a destination increases or if congestion is higher due to road damage.
2 O&M of vehicles	X		X	X	The cost of operating a vehicle increases if the distance to reach a destination increases.
3 O&M of roads	X		X	X	The O&M costs of roads that are used more intensively as a result of diversions increase due to the higher volume of vehicles and congestion.
4 Cost of time		X	X	X	Travel time refers to the extra time required to reach a given destination that increases due to congestion and greater distances when road damage occurs.
5 Air pollution		X		X	Air pollution refers to the introduction of chemicals, particulate matter, and biological material into the atmosphere that cause or have the potential to cause harm or discomfort to humans.
6 Noise pollution		X		X	Noise pollution is the presence of a noticeable extent of noise that presents an irritation or loss of amenities for those exposed to it. It can also cause health impacts.
7 Water pollution		X		X	Transport-related water pollution is defined as the contamination of waterbodies, potentially posing a threat to the natural environment and, ultimately, human health.
8 GHG emissions		X		X	Gases that trap heat within the atmosphere are often referred to as GHGs, in this case generated from the use of liquid fuels.

	Type of impact		Who is impacted		
Indicators	**Tangible**	**Intangible**	**Businesses**	**People**	**Comments**
9 Nature and landscape		X		X	Transport projects commonly influence natural vegetation and landscape in some form. The development of land-based transportation can lead to the loss of ecosystem services that are key for human well-being
10 Crop and fruit revenue	X		X		If a road is impassible or partially damaged, it can impact market access for business (i.e., sales decline due to the fact that delivery is lower than usual).
11 Fish revenue	X		X		
12 Livestock revenue	X		X		
13 Access to essential services		X		X	The delivery of a certain product or service can be impacted negatively by the presence of road damage (e.g., medicine, food delivery).
14 Access to workplace and schools		X		X	If a road is impassible or partially damaged, it can impact access to workplace and schools, resulting in possible loss of income.
15 Mental health		X		X	This is the impact on mental health due to road disruption, for instance as a result of isolation.

4.0 Quantifying Non-Road Impacts

This section offers an overview of the calculations performed and included in the Excel-based model to estimate the physical and economic value of all non-roads benefits of investments in betterment.

4.1 Fuel Costs (Item 1)

Fuel costs can be calculated using information on the total km of road diversion, the number of people impacted, the vehicle ownership per person, the trips taken per day, the total days of road interruption, the average fuel consumption per km, and the fuel price.

The steps to calculate the additional fuel costs are as follows:

1. First, we calculate the km of extra travel using the formula below:

$$\textit{Km of extra travel} = \textit{km of diversion} * (\textit{People impacted/vehicle ownership per person}) * \textit{Trips taken per day} * \textit{Days of road interruption}$$

2. Second, we multiply the km of extra travel by the average fuel consumption per km to arrive at the additional fuel consumption

$$\textit{Additional fuel consumption} = \textit{km of extra travel} * \textit{Average fuel consumption per km}$$

3. Finally, we multiply the additional fuel consumption by the fuel price to obtain the additional fuel costs

$$\textit{Additional fuel costs} = \textit{Additional fuel consumption} * \textit{Fuel price}$$

4.2 O&M Costs for Vehicles (Item 2)

To calculate the O&M costs for vehicles, the Cost-Benefit Analysis (CBA) Manual, Road Projects (Connecting Queensland, 2021) was used as the basis for understanding basic repairs and servicing costs for different vehicle types per km travelled, shown in Table 4. Multiplying these costs by the number of extra km travelled (extra km per person, multiplied by the population impacted) allows the estimation of additional vehicle O&M costs. The values in the table have been adjusted to account for the 2022 Consumer Price Index (CPI) to account for household inflation to reflect real-time cost of goods from 2007 to 2021 (Australian Bureau of Statistics, 2022).

Table 4. Repairs and servicing cost

Vehicle type	Basic repairs and servicing cost (cents/km) (CPI -adjusted from 2007)
Cars – private	6.15
Cars – commercial	6.29
Non-articulated	11.76
Buses	11.76
Articulated	22.70
B-double	28.17
Road train 1	30.08
Road train 2	38.56

4.3 O&M Costs for Roads (Item 3)

Periodic (every 5 years) and annual maintenance of roads require 39.1 tonnes/km and 1.2 tonnes/km, respectively (National Transport Development Policy Committee, 2012). Maintenance of roads using recycled materials costs USD 3.7/tonne and USD 11.9/tonne using virgin materials (Bassi et al., 2017). By multiplying the total km of road diversion by the annual maintenance and the increased periodic maintenance (and also by a mix of recycled and virgin materials used for O&M operations), it would be possible to calculate the increase in O&M costs.

4.4 Cost of Travel Time (Item 4)

The *CBA Manual* (Connecting Queensland, 2021) was used to estimate the value of time for both passenger transport and freight (Table 3). Costs are based on occupancy rates provided for urban and rural environments. The manual assigns a different value of time to different vehicle types in urban and rural contexts. This is to account for value of time for businesses versus private citizens and for the higher occupancy of public transport versus private vehicles. In other words, an hour of delay due to traffic is worth more for a bus than a single private vehicle because the bus carries more passengers. Similarly, an hour of delay due to traffic for a commercial vehicle may be worth more than a single private vehicle due to the nature of business performed (i.e., an hour of delay for a business can be directly converted into a cost opportunity or loss of revenues while the delay for a private citizen represents an intangible cost).

Multiplying these cost figures by the number of extra km traveled due to road damage, and by the population affected allows the model to estimate the cost of additional travel. Data on the population affected and the use of urban vs. rural values can be informed by the use of spatial data. The values in the table have been adjusted to account for the CPI (Australian Bureau of Statistics, 2022).

Table 5. Estimated values of travel time – occupant and freight payload values

Estimated values of travel time

Vehicle type	Environment	Total value of time ($/vehicle hour)
Cars – private	Rural	26.70
	Urban	25.13
Cars – commercial	Rural	56.90
	Urban	61.27
Non-articulated	Rural	40.13
	Urban	44.70
Buses	Rural	188.52
	Urban	238.31
Articulated	Rural	52.99
	Urban	72.87
B-double	Rural	66.17
	Urban	100.22
Road train 1	Rural	78.99
	Urban	35.70
Road train 2	Rural	100.85
	Urban	34.78

Source: Connecting Queensland, 2021.

4.5 Externalities of Vehicle Use (Items 5, 6, 7, 8, 9)

The CBA Manual (Connecting Queensland, 2021) was also used to determine the monetary costs for passenger vehicles and buses (Table 4) and freight vehicles (Table 5) related to air pollution, GHGs, noise, water pollution, and nature and landscape. Multiplying these costs by the number of extra km travelled (extra km per person multiplied by the population impacted) allows the model to estimate various externalities. The values in the tables have been adjusted to account for the CPI (Australian Bureau of Statistics, 2022).

Table 6. Externality unit costs for passenger vehicles and buses

Externality unit costs for passenger vehicles and buses (cents per vehicle kilometres travelled) (CPI-adjusted from 2007)

	Urban		Rural	
	Passengers cars	**Buses**	**Passengers cars**	**Buses**
Air pollution	3.47	39.12	0.04	-
GHGs	2.73	16.12	2.73	16.12
Noise	1.12	2.73	-	-
Water	0.52	5.87	0.05	0.05
Nature and landscape	0.07	0.18	0.64	1.78

Source: Connecting Queensland, 2021.

Table 7. Externality unit costs for freight vehicles

Externality unit costs for freight vehicles ($ per 1,000 tonne-km) (CPI from 2007)

	Urban		Rural	
	Light vehicles	**Heavy vehicles**	**Light vehicles**	**Heavy vehicles**
Air pollution	217.30	28.97	-	0.29
GHGs	67.68	6.44	67.68	6.44
Noise	37.05	4.84	-	0.48
Water	32.60	4.35	0.33	1.74
Nature and landscape	24.17	0.48	0.25	4.84

Source: Connecting Queensland, 2021.

4.6 Lost Crop and Fruit Revenue (Item 10)

To calculate the lost productivity due to a road being impassible and, hence, impacting market access, the following formula has been used:

*total area affected (ha) * land productivity (tonnes/ha) * crop price ($/tonnes)*

In an instance where data are not available on the area impacted by the road damage, spatial tools could be used to generate an estimate. For instance, QGIS—a free geographic information system—could be used to create a buffer around the road (i.e., the area that could potentially be impacted, e.g., 1 km radius). This buffer area could then be used to estimate the production (based on the crops grown in the area, and land productivity) that is impacted by delays in reaching the market. The estimation of lost productivity (or the quantity that does not reach the market) can be informed by crop yield data from open source food and agriculture data through FAOSTAT (Food and Agriculture Organization of the United Nations [FAO], 2021) multiplied by lost market access (%). The share of lost market access should be assessed case by case or through a sensitivity analysis. The crop price can be derived from national/local data or other databases (such as FAOSTAT). Please note that the term "crop" also includes fruit and horticultural products.

4.7 Lost Fish Revenue (Item 11)

To calculate the lost revenues for fisheries when a road is impassible, thus impeding market access, the following formula has been used:

*total kg of fish transported * production value per kg ($/kg)*

The estimation of lost revenues (or the quantity that does not reach the market) will require data on production and trade and an assessment of the % reduction of market access due to road damage.

4.8 Lost Livestock Revenue (Item 12)

To calculate the lost revenue when a road is impassible and market access is impacted, the following formula has been used:

*total affected animals (heads) * revenue per animal ($/head)*

The estimation of lost revenues (or the quantity that does not reach the market) can be informed by livestock yield data from FAOSTAT (FAO, 2021) multiplied by lost market access (%). The livestock price can be derived from national/local data or other databases (such as FAOSTAT).

Damage to livestock that occurs as a result of dust inhalation and jarring on unpaved or unsealed roads has also been calculated. This data is driven from the *CBA Manual* (Connecting Queensland, 2021) which is based on the change in road state between the base and project cases (or the road normally available, e.g., gravel, compared to the one that may be built as a result of damage, e.g., bitumen). The values in Table 8 have been adjusted to account for the CPI (Australian Bureau of Statistics, 2022). Multiplying these values by the number of extra km travelled (extra km per vehicle), by the number of days of road interruption, and by the total number of vehicles carrying livestock, allows the tool to estimate the damage to livestock that occurs as a result of dust inhalation and jarring on unpaved or unsealed roads. These parameters can be set in the model in the "key inputs & outputs" sheet.

Table 8. Livestock damage

	Damage due to dust inhalation and jarring on unpaved or unsealed roads ($/km)		
Vehicle type	**Unsealed/formed road to sealed road**	**Unsealed/formed road to gravel/paved road**	**Paved road to sealed road**
Articulated	0.952	1.091	1.225
B-double	0.124	0.540	0.952
Road train 1	0.124	0.540	0.952
Road train 2	0.124	0.540	0.952

4.9 Access to Essential Items/Services (Item 13)

To calculate the impact of reduced access to essential items and services, we multiply the number of people impacted by the cost of delivery per person for a given product or service that is impacted by road damage. An initial benchmark value of AUD 100 per person impacted per day is considered in the model. On the other hand, this value should be modified to reflect any specific reduced access to items and services that would emerge as a result of road damage.

4.10 Access to Workplace and Schools (Item 14)

To calculate the impact on access to workplaces and schools, the number of people impacted has been multiplied by the % of those who are not able to go to school and/or work (nor to perform work from home), is used to obtain the total number of people that are not able to work as a result of the road damage. This value has been multiplied by the average salary per person (e.g., daily or monthly salary), and by the number of days/months of road interruption.

In the case of interrupted school access, it has been assumed that parents (or anyone taking care of them) are not able to work. As a result, it is important to note that this calculation may be seen as an overestimation of the economic impact of road damage on access to the workplace and schools (e.g., some parents may take vacation days to look after children without having an impact on their monthly salary).

4.11 Mental Health Impacts (Item 15)

To calculate mental health impacts, the Australian Institute of Health and Welfare report (2022) on the cost of mental health-related services in Australia during 2019–2020 was used, which amounts to AUD 431 per person. In the model, it is assumed that this is the cost per person per year, and then the specific cost per event based on the duration of the road damage has been estimated using this figure (e.g., if the road damage lasts 6 months, we consider AUD 215.5 per person in mental health cost for that specific road damage event).

5.0 Using the Model: Parametrization and interpretation of results

The input parameters of the Excel-based model need to be customized for each new road infrastructure project/investment analyzed. To do this, two main tasks must be performed:

(i) Selection of the impacts/indicators that apply to the case study (e.g., not all road damage events will impact market access or may only do so for agriculture production and not for fish).

(ii) Parametrization of the model for the impacts considered.

Both tasks require interaction with the model to modify the data that is specifically relevant to the project/investment.

The selection of indicators of relevance and the values used for their parametrization, affect the results of the model. Two examples are provided below to highlight the extent to which model results may change when considering road damage (and related betterment investment) in a rural vs. urban context. An additional example is provided to show results for an investment that is not economically viable.

5.1 Example 1: Rural context

The first example is one in which only an agricultural area has been affected by road damage. This means all the non-road benefits have been excluded (such as 4. Air pollution, 15. Mental health, etc.), apart from "10. Crop and fruit revenue" as well as the costs shown in Table 9.

The rationale for excluding certain indicators is that in a rural context, these will not have a material impact (e.g., air quality may be good and, hence, there is no impact on air quality and human health from shifting the already limited traffic to a different road). This is an extreme case example where several indicators have been removed from the analysis.

Table 9. Example 1 - Summary of inputs

Non-road benefits in 2021 prices		
1 Fuel cost	720	AUD/day
2 O&M cost of vehicles	46	AUD/day
3 O&M cost of roads	10	AUD/day
4 Cost of travel time	-	AUD/day
5 Air pollution	-	AUD/day
6 Noise pollution	-	AUD/day
7 Water pollution	-	AUD/day
8 GHG emissions	-	AUD/day
9 Nature and landscape	-	AUD/day
10 Crop and fruit revenue	16,338	AUD/day
11 Fish revenue	-	AUD/day
12 Livestock revenue	-	AUD/day
13 Access to essential items/services	-	AUD/day
14 Access to workplace and schools	-	AUD/day
15 Mental health	-	AUD/day

The results of the analysis are summarized in Table 10. They show that the investment is economically viable: non-road benefits increase the BCR of 2.47, and the IRR is between 12.4% and 17%, with an NPV of AUD 6 million when considering non-road benefits.

Table 10. Example 1 – Results

BCR		IRR		NPV	
Excluded non-road benefits	**Included non-road benefits**	**Excluded non-road benefits**	**Included non-road benefits**	**Excluded non-road benefits**	**Included non-road benefits**
2.01	2.47	12.4 %	17.0 %	AUD 3,540,960	AUD 6,095,461

5.2 Example 2: Urban context

The second example demonstrates a situation where only indicators of relevance to urban areas have been considered. As a result, all the non-road benefits have been included, apart from "10. Crop and fruit revenue," "11. Fish revenue," and "12. Livestock revenue" as shown in Table 11 to demonstrate a situation where access to produce and agriculture is not impacted. In this extreme case, it is considered that the indicators that were excluded previously are now included as part of the analysis.

Table 11. Example 2 – inputs

Non-road benefits in 2021 prices			%
1 Fuel cost	720	AUD/day	5.9 %
2 O&M cost of vehicles	46	AUD/day	0.4 %
3 O&M cost of roads	10	AUD/day	0.1 %
4 Cost of travel time	501	AUD/day	4.1 %
5 Air pollution	1,656	AUD/day	13.5 %
6 Noise pollution	286	AUD/day	2.3 %
7 Water pollution	248	AUD/day	2.0 %
8 GHG emissions	528	AUD/day	4.3 %
9 Nature and landscape	182	AUD/day	1.5 %
10 Crop and fruit revenue	-	AUD/day	-
11 Fish revenue	-	AUD/day	-
12 Livestock revenue	-	AUD/day	-
13 Access to essential items/services	5,000	AUD/day	40.9 %
14 Access to workplace and schools	3,000	AUD/day	24.5 %
15 Mental health	59	AUD/day	0.5 %

The results of the analysis are summarized in Table 12. The results show that the investment is also economically viable, with positive IRR, NPV, and a BCR above 1. All the results that exclude non-road benefits are the same, while a difference emerges when considering the value of non-road benefits.

More specifically, the results show a comparatively lower economic performance relative to the first example. In other words, the value of market access for businesses is estimated to be higher in these specific examples than the value of urban non-road benefits. This is clear when reviewing the results that include non-road benefits: the IRR is 15.7% instead of 17%; the BCR is 2.34 instead of 2.47; and the NPV is AUD 5.37 million instead of AUD 6.10 million.

Table 12. Example 2 – results

BCR		IRR		NPV	
Excluded non-road benefits	Included non-road benefits	Excluded non-road benefits	Included non-road benefits	Excluded non-road benefits	Included non-road benefits
2.01	2.34	12.4 %	15.7%	AUD 3,540,960	AUD 5,367,388

5.3 Example 3: Focus on economic and financial viability

The examples presented above are economically viable, having an IRR higher than the discount rate assumed, and hence positive NPV and a BCR above 1. On the other hand, this may not always be the case. For instance, if the investment is made, but only a few road damages are avoided in subsequent years, the investment may not be financially or economically viable.

For instance, Table 13 shows an example in which, starting from the urban case presented above, the "avoided road damage benefit based on past occurrences" declines from AUD 6,700,000 to AUD 4,500,000 (i.e., the number of avoided road damage occurrences in the past is reduced from 4 to 2). The reduction in tangible avoided costs makes it so that the results for the "non-road benefits" scenario show a negative IRR (minus 3.4%), negative NPV (minus AUD 1.6 million) and a BCR smaller than one. On the other hand, when the non-road benefits are included, the BCR and the IRR are slightly positive (1.02 and 0.7%), but the NPV remains negative (because the IRR is smaller than the discount rate used).

This example highlights that (i) some projects may not be financially nor economically viable, and that (ii) it may well be that a project is not financially viable, but it is worth investing in from an economic perspective that includes non-road benefits.

Table 13. Example 3 – results

BCR		IRR		NPV	
Excluded non-road benefits	Included non-road benefits	Excluded non-road benefits	Included non-road benefits	Excluded non-road benefits	Included non-road benefits
0.90	1.02	(3.4%)	0.7%	AUD (1,637,173)	AUD (855,405)

5.4 Example 4: Aurukun Access Road

The Aurukun Access Road was a gravel road, the only road link to and from the Aurukun community in Queensland (QRA, 2022). This road was damaged four times between 2010 and 2013, when betterment funding was used to bitumen-seal a 10-km section of the road that was vulnerable to flooding. Since then, the road has withstood the impacts of eight separate extreme climate events.

In summary, the available information for model parametrization is:

- Km of diversion: 10 km
- Betterment costs: AUD 1,092,406
- Avoided cost over eight extreme climate events: AUD 6,726,214

To calculate the avoided costs emerging from the implementation of the betterment project, the assumptions shown in Table 14 were used. A very important assumption is the number of days of avoided road service interruption (see Section 4), which is set at 45 days (i.e., the time for which the road would not be fully available when climate-related damage occurs, which corresponds to the time required to complete reconstruction work after the extreme climate event). Other model inputs are required, such as the number of people impacted (assumed to be 50 in this case out of a total population for Aurukun of approximately 1,270 people) as presented in Section 6.

Table 14. Base inputs

Base inputs		
Km of diversion	10.0	km
People impacted per day	50	people
Vehicle ownership per person	0.50	vehicle/person
Number of vehicles impacted	25.0	vehicles
Number of freight vehicles	5	vehicles
Tonnes transported by freight vehicles	50.0	tonnes
Vehicle speed	40.00	km/h
Crop and fruit revenue - type	Maize	type
Crop and fruit revenue - list number	13	list number
Crop and fruit revenue - Lost market access per day (%)	2.00 %	%
Kg of fish transported	50.00	kg
Livestock revenue - type	Meat, chicken	type
Livestock revenue - list number	2	list number
Livestock revenue - Lost market access per day (%)	2.00 %	%
Number of vehicles carrying livestock	20.00	vehicles

The base inputs shown in Table 14 are used to calculate the non-road benefits shown in Table 15.

Table 15. Example 3 – inputs

Non-road benefits in 2021 prices			%
1 Fuel cost	240	AUD/day	2.1 %
2 O&M cost of vehicles	15	AUD/day	0.1 %
3 O&M cost of roads	3	AUD/day	0.0 %
4 Cost of travel time	167	AUD/day	1.5 %
5 Air pollution	552	AUD/day	4.8 %
6 Noise pollution	95	AUD/day	0.8 %
7 Water pollution	83	AUD/day	0.7 %
8 GHG emissions	176	AUD/day	1.5 %
9 Nature and landscape	61	AUD/day	0.5 %
10 Crop and fruit revenue	1,689	AUD/day	14.8 %
11 Fish revenue	70	AUD/day	0.6 %
12 Livestock revenue	220	AUD/day	1.9 %
13 Access to essential items/services	5,000	AUD/day	43.7 %
14 Access to workplace and schools	3,000	AUD/day	26.2 %
15 Mental health	59	AUD/day	0.5 %
Non-road benefits in 2021 prices	**11,431**	**AUD/day**	100.0 %

The results of the analysis shown in Table 16 indicate that the BCRs including and excluding non-road benefits are both larger than 6, while the IRRs are positive, both being larger than 140%. These results show that the project was both economically and financially viable. Further, the results show that the benefits are primarily emerging from direct road benefits rather from the non-road benefits.

Table 16. Example 3 – results

BCR		IRR		NPV	
Excluded non-road benefits	**Included non-road benefits**	**Excluded non-road benefits**	**Included non-road benefits**	**Excluded non-road benefits**	**Included non-road benefits**
6.16	6.63	140.2 %	151.3%	AUD 7,350,917	AUD 8,040,066

6.0 Structure of the Excel-Based Model

This section of the document provides information on how the Excel-based model is structured, with each subsection referring to a specific sheet of the model.

6.1 Guide

This sheet can be used as a glossary and explains the meaning of the different colours used in the model, as well as how to navigate through the different cells. Cells highlighted with a light yellow shade require user input, blue font reflects a link from another sheet, and red font reflects a link to another sheet. Black font reflects calculations performed by the model.

6.2 Key Inputs and Outputs

This sheet provides the base inputs, and offers the option of creating alternative parametrizations/scenarios (up to six pre-determined cases) (Figure 1) for each road project/investment entered into the tool. These values must be changed manually.

This sheet also summarizes the non-road benefits, the value statement of the project, the number of extreme weather events and their occurrence over time, and, finally, the economic and financial key metrics across a maximum of six case studies (Figure 2).

This sheet offers a complete overview of model inputs (top of the sheet) and model outputs (bottom of the sheet).

Importantly, another sheet must be considered for including information on the frequency of past and future avoided extreme climate events: "Analysis" (specifically rows 38 and 43).

Figure 1. Key model inputs

Key inputs & outputs — **Active case: Base case**

Label	Ref	Value	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Case 1		1	case #						
Case description		Base case	case label	Base case	10% across the board downside	10% across the board upside			
Base inputs									
Km of diversion		30.0	km	30.0	30.0	30.0			
People impacted per day		50	people	50	50	50			
Vehicle ownership per person		0.50	vehicle/perso	0.50	0.50	0.50			
Number of vehicles impacted		25.0	vehicles						
Number of freight vehicles		5	vehicles	5	5	5			
Tonnes transported by freight vehicles		50.0	tonnes	50.0	50.0	50.0			
Vehicle speed		40.00	km/h	40.00	40.00	40.00			
Crop and fruit revenue - type		Apples	type	Apples	Apples	Apples			
Crop and fruit revenue - list number		1	list number						
Crop and fruit revenue - Lost market access per day (%)		2.00 %	%	2.00 %	2.00 %	2.00 %			
Kg of fish transported		50.00	kg	50.00	50.00	50.00			
Livestock revenue - type		Meat, cattle	type	Meat, cattle	Meat, cattle	Meat, cattle			
Livestock revenue - list number		1	list number						
Livestock revenue - Lost market access per day (%)		2.00 %	%	2.00 %	2.00 %	2.00 %			

Figure 2. Key model outputs

Key inputs & outputs — Active case: Base case

Label	Ref	Value	Unit	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
KEY OUTPUTS									
Copy-paste-value active output values (in column F) into stored output columns (columns H onwards)									
Non-road benefits in 2021 prices									
1 Fuel cost		720	AUD/day	720	648	792			
2 O&M cost of vehicles		46	AUD/day	46	42	51			
3 O&M cost of roads		10	AUD/day	10	9	11			
4 Cost of travel time		501	AUD/day	501	451	551			
5 Air pollution		1,656	AUD/day	1,656	1,490	1,821			
6 Noise pollution		286	AUD/day	286	258	315			
7 Water pollution		248	AUD/day	248	224	273			
8 GHG emissions		528	AUD/day	528	475	581			
9 Nature and landscape		182	AUD/day	182	164	200			
10 Crop and fruit revenue		16,338	AUD/day	16,338	14,704	17,972			
11 Fish revenue		70	AUD/day	70	63	77			
12 Livestock revenue		1,148	AUD/day	1,148	1,033	1,263			
13 Access to essential items/services		5,000	AUD/day	5,000	4,500	5,500			
14 Access to workplace and schools		3,000	AUD/day	3,000	2,700	3,300			
15 Mental health		59	AUD/day	59	53	65			
Non-road benefits in 2021 prices		29,792	AUD/day	29,792	26,813	32,771			
Value Statement in 2021 prices									
Betterment cost		(5,000,000)	AUD	(5,000,000)	(5,000,000)	(5,000,000)			
Historical avoided road damage benefit		6,700,000	AUD	6,700,000	6,700,000	6,700,000			
Future avoided road damage benefit		3,350,000	AUD	3,350,000	3,350,000	3,350,000			

6.3 Other Inputs

This sheet shows the input value for all assumptions that are parametrized using literature reports. These can be considered "secondary" inputs that may not require changing when working across different investments/case studies (Figure 3). All key inputs that should be continuously reviewed and adjusted to a specific case study are included in the "Key inputs & Outputs" sheet.

Figure 3. Other inputs

10 Crop and fruit revenue				
Select type from dropdown list:				
Apples	1	list number		
CPI (1 AUD in 2020 vs 1 AUD in 2021)	1.032	index		
	Yield	**Producer prices**	**Producer prices**	
	2020 values	2020 prices	2021 prices	Reference:
2021 prices	tonnes/ha	USD/Tonne	USD/Tonne	https://www.fao.org/faostat/en/#data
Apples	15.93	1,420	1,465	
Avocados	4.66	2,917	3,009	
Bananas	30.39	1,196	1,234	
Barley	2.01	204	211	
Beans, green	5.42	3,130	3,230	
Berries nes	2.55	7,817	8,065	
Cabbages and other brassicas	34.67	601	620	
Carrots and turnips	56.94	634	655	
Cauliflowers and broccoli	12.56	824	850	
Cherries	6.86	9,679	9,987	
Chick peas	1.07	524	540	
Lettuce and chicory	21.97	1,256	1,296	
Maize	7.09	330	340	
Maize, green	11.73	1,376	1,419	
Mangoes, mangosteens, guavas	3.82	1,886	1,946	
Melons, other (inc.cantaloupes)	34.00	594	613	
Mushrooms and truffles	371.02	4,814	4,967	

6.4 Non-Road Benefits Calculations

This is the model sheet where all calculations are performed to convert model input into useful values for the CBA (e.g., single values per km or per person, are multiplied by the km of road damage and by the number of people impacted) (Figure 4).

Figure 4. Non-road benefits calculations

Non-road benefits calcs — **Active case: 10% across the board downside**

Label	Value	Unit	Comment
1 Fuel cost			
Km of diversion	30.0	km	
People impacted per day	50	people	
Vehicle ownership per person	0.50	veh/person	
Trips per day	2.00	veh/day	
Km of extra travel	6,000	km	
Average fuel consumption per km	0.08	liter/100 km	
Additional fuel consumption	480.00	liter	
Fuel price	1.50	AUD/liter	
1 Fuel cost - sensitivity factor	0.900	factor	
1 Fuel cost	648	AUD/day	

6.5 Analysis

This is the model sheet where the CBA is estimated. Below is a list of the main elements included in this sheet:

- First, it summarizes all key inputs for the calculations (top part of the sheet), as shown in Figure 5. This table contains all the estimated non-road benefits (estimated on a "per-day" basis).

Figure 5. Non-road benefits

Non-road benefits in 2021 prices			%
1 Fuel cost	720	AUD/day	5.9 %
2 O&M cost of vehicles	46	AUD/day	0.4 %
3 O&M cost of roads	10	AUD/day	0.1 %
4 Cost of travel time	501	AUD/day	4.1 %
5 Air pollution	1,656	AUD/day	13.5 %
6 Noise pollution	286	AUD/day	2.3 %
7 Water pollution	248	AUD/day	2.0 %
8 GHG emissions	528	AUD/day	4.3 %
9 Nature and landscape	182	AUD/day	1.5 %
10 Crop and fruit revenue	-	AUD/day	-
11 Fish revenue	-	AUD/day	-
12 Livestock revenue	-	AUD/day	-
13 Access to essential items/services	5,000	AUD/day	40.9 %
14 Access to workplace and schools	3,000	AUD/day	24.5 %
15 Mental health	59	AUD/day	0.5 %

- Second, it shows the calculations made for each year for the full lifetime of the project (including past and future years), as shown in Figure 6. In the first row, the years considered are shown, starting from when the betterment project was implemented. For the following years, the avoided road damages are estimated and include avoided past events as well as the forecasted ones. Specifically, the daily non-road benefits are estimated multiplying the daily cost coefficients by the duration of the road disruption for the years in which an extreme event occurs.

Figure 6. Calculations

Modelling period ending						31 Dec 14	31 Dec 15	31 Dec 16	31 Dec 17	31 Dec 18	31 Dec 19	31 Dec 20	31 Dec 21	31 Dec 22	31 Dec 23	31 Dec 24	31 Dec 25
Column counter	Ref	Constant	Unit	Total		1	2	3	4	5	6	7	8	9	10	11	12
Placing costs and benefits in time																	
Betterment cost																	
Betterment cost	-	5,000,000	AUD														
Betterment event occurrence flag			flag	1		1											
Betterment cost			AUD	(5,000,000)		(5,000,000)	-	-	-	-	-	-	-	-	-	-	-
Avoided road damage benefit																	
Avoided road damage benefit based on past occurences	-	6,700,000	AUD														
Number of past occurences	-	4	occurences														
Avoided road damage benefit per event		1,675,000	AUD/event														
Avoided road damage event occurrence flag			flag	6				1		1		1	1		1		1
Avoided road damage benefit			AUD	10,050,000		-	-	1,675,000	-	1,675,000	-	1,675,000	1,675,000	-	1,675,000	-	1,675,000
Non-road benefits																	
Non-road benefits in 2021 prices		12,236	AUD/day														
Non-road event occurrence and duration			days	135				25		25		25	25		15		20
Non-road benefits			AUD	1,651,879		-	-	305,904	-	305,904	-	305,904	305,904	-	183,542	-	244,723
Value Statement in 2021 prices																	
Betterment cost		-	AUD	(5,000,000)	-	(5,000,000)	-	-	-	-	-	-	-	-	-	-	-
Avoided road damage benefit		-	AUD	10,050,000	-	-	-	1,675,000	-	1,675,000	-	1,675,000	1,675,000	-	1,675,000	-	1,675,000
Net benefits excl. non-road benefits			AUD	5,050,000		(5,000,000)	-	1,675,000	-	1,675,000	-	1,675,000	1,675,000	-	1,675,000	-	1,675,000
Non-road benefits		-	AUD	1,651,879	-	-	-	305,904	-	305,904	-	305,904	305,904	-	183,542	-	244,723
Net benefits incl. non-road benefits			AUD	6,701,879		(5,000,000)	-	1,980,904	-	1,980,904	-	1,980,904	1,980,904	-	1,858,542	-	1,919,723

Figure 7. Analysis

Non-road benefits in 2021 prices	67,669	AUD/day	100.0 %	
Placing costs and benefits in time				
Betterment cost				
Betterment cost	5,000,000	AUD		
Betterment event occurrence flag		flag	1	
Betterment cost		AUD	(5,000,000)	
Avoided road damage benefit				
Avoided road damage benefit based on past occur	6,700,000	AUD		
Number of past occurences	4	occurences		
Avoided road damage benefit per event	1,675,000	AUD/event		
Historical avoided road damage event occurrence flag		flag	4	
Historical avoided road damage benefit		AUD	6,700,000	
Future avoided road damage event occurrence flag		flag	2	
Future avoided road damage benefit		AUD	3,350,000	
Non-road benefits				
Non-road benefits in 2021 prices	67,669	AUD/day		
Non-road event occurrence and duration		days	135	
Non-road benefits		AUD	9,135,276	
Value Statement in 2021 prices				
Betterment cost	-	AUD	(5,000,000)	#
Historical avoided road damage benefit	-	AUD	6,700,000	#
Future avoided road damage benefit	-	AUD	3,350,000	#
Net benefits excl. non-road benefits		AUD	5,050,000	
Non-road benefits	-	AUD	9,135,276	#
Net benefits incl. non-road benefits		AUD	14,185,276	
Benefits to Costs Ratio (BCR)				
Historical avoided road damage benefit	-	AUD	6,700,000	
Future avoided road damage benefit	-	AUD	3,350,000	
Total avoided road damage benefit over time		AUD	10,050,000	
Betterment cost	-	AUD	(5,000,000)	
BCR excl. non-road benefits	**2.01**	ratio		
Historical avoided road damage benefit	-	AUD	6,700,000	
Future avoided road damage benefit	-	AUD	3,350,000	
Non-road benefits	-	AUD	9,135,276	
Total benefit over time incl. non-road benefits		AUD	19,185,276	

6.6 References and Notes

This sheet presents the references used in the model. It offers a specific reference to the source of the data as well as a definition of the impact considered (Figure 8).

Figure 8. References and notes

References & Notes

#	Reference
1	https://www.abs.gov.au/statistics/economy/price-indexes-and-inflation/consumer-price-index-australia/latest-release
2	Cost Benefit Analysis (CBA) Manual, Transport and Main Roads, March 2021
3	The emission of air pollutants from transportation mainly consists of exhaust emissions, but there are also impacts of fuel vapours and emissions that result from the contact between vehicles' tyres and the road surface. Emissions also vary by type of vehicle (truck, private car, engine size and model) and fuel (diesel/ petrol).
4	Transportation is a significant source of greenhouse gas (GHG) emissions, which are defined in the National Greenhouse Gas Inventory (NGGI) as emissions from the direct combustion of fuels in road transportation, railways, navigation, aviation and off-road recreational vehicle activity
5	The prevailing source of artificial noise pollution in built-up areas is from transportation. In rural areas, train and aviation noise can disturb wildlife habitats. Trucks and exhaust braking is a significant contributor of noise pollution in rural towns.
6	Transport-related water pollution is defined as the contamination of water bodies such as lakes, rivers, oceans and groundwater, which can be harmful to local and even regional ecological values
7	Transport projects commonly influence natural vegetation and landscape in some form. The development of land-based transportation has led to deforestation, habitat loss, loss of natural vegetation, reduction in the quality of landscape, land pollution and reduction in visual amenity.
8	https://www.fao.org/faostat/en/#data
9	https://www.aihw.gov.au/reports/mental-health-services/mental-health-services-in-australia/report-contents/expenditure-on-mental-health-related-services
##	https://silo.tips/download/life-cycle-analysis-of-transport-modes
##	https://www.iisd.org/system/files/publications/sustainable-asset-valuation-tool-roads.pdf and Data from SAVi Model

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